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The Relationship between Amount of Training and Performance on a New Task

Jacinta Avril Tan

A report submitted in Partial Fufilment of the Requirements for the Award of Bachelor of

Science (Psychology) Honours, Faculty of Computing, Health and Science, Edith Cowan

University,

Submitted (October, 2010)

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Abstract

This paper was designed to examine the relationship between training and transfer tasks and performance on these tasks whereby training can be used to predict transfer. Previous research has assumed that performance of an established task should extrapolate the power function of learning. That is, performance of an established skill in a new domain will continue to improve at the same rate with practice as if there was no change in the domain. 60 participants were recruited from the University of Edith Cowan and were randomly assigned to one of three conditions; 10 block condition, 20 block condition, or 30 block condition. Participants were required to complete a dot counting task. The training and transfer phases differed such that the items presented in the transfer phase were also present in the training phase but with additional items. The results revealed that performance of old skills executed in the context of a new task were slower than predicted in the 10 and 30 block condition. These results indicated that a change in the presentation context of a new task affects response time performance on an old task, and extrapolations of the learning curve cannot be applied to predicting transfer performance.

Author: Jacinta Avril Tan

Supervisor: Professor Craig Speelman

Submitted: October 2010

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I would firstly like to thank Professor Craig Speelman for sharing his knowledge and contributing his time. Without his guidance and supervision, this task would have been more challenging.

Secondly, I would like to thank the participants of this study. Without their participation, my thesis would not be completed.

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Figures:

The Relationship between Amount of Training and Performance on a New Task

While past research has centered on how humans acquire and perform a variety of skills, recent research has advanced to focus on the relationship between training and transfer tasks and performance on these tasks with the ultimate aim of developing a set of principles whereby training can be used to predict transfer (Speelman & Kirsner, 2001). Skill acquisition usually involves the improvement in the speed of performance through practicing a particular task for an extended period of time (Speelman & Kirsner, 2005). Current theories of skill acquisition have agreed that practice is an important precursor to skilled performance (Speelman & Kirsner, 1997). Skill acquisition has been demonstrated in several studies such as syllogistic reasoning (Speelman & Kirsner, 1997; Speelman & Kirsner, 2005), counting (Lassaline & Logan, 1993), lexical decision (Logan, 1990; Kirsner & Speelman, 1996), arithmetic skills (Rickard, Healy, & Bourne, 1994), letter search (Schneider & Fisk, 1984), role of processing strategies (Doane, Sohn, & Schreiber, 1999), serial reaction time task (Roberson, 2007), driving (Groeger & Banks, 2007), authorship of science fiction books (Ohlsson, 1992), and many other tasks.

It is pertinent to focus on how transfer can be predicted on the basis of training performance as it has extended the significance of the much discussed topic of skill acquisition and transfer performance. That is, aside from focusing on how much training performance enables transfer to be predicted, the extent of transfer between two tasks is presently included in voluminous research on skill acquisition (Speelman & Kirsner, 2001).

The aim of the present research was to examine whether it is possible to predict transfer performance based on the amount of training experienced. Previous research has assumed that performance of an established skill in a new domain will continue to improve at the same rate with practice as if there was no change. However, a limitation in previous literature of this assumption is that two sources of information have been neglected, mainly

accuracy and the distribution of reaction times. Some researchers (e.g., Dosher & Lu, 2007; Nosofsky & Alfonso-Reese, 1999) who have taken response accuracy into consideration have tended to ignore reaction times or interpreted both reaction time and accuracy as separate variables even though reaction time and accuracy are closely related (Forstmann, Dutilh, Brown, Neumann, von Cramon, Ridderinkhof, & Wagenmakers, 2008). While there is an abundance of literature on the relationship of skill acquisition and transfer, there is a dearth of research on whether good performance in training is able to predict the extent of disruption in transfer. In order to investigate this, some of the critical features of skill acquisition and transfer will be discussed in this paper.

Power law of learning

A central concept in skill acquisition research is the power law of learning (DeKeyser, 2007). Newell and Rosenbloom (1981 as cited in Palmeri, 1999) observed that performance measures such as error rate and reaction time, improve with practice across nearly every task, and the relationship between practice and performance is one where diminishing marginal gains are made with increased practice while substantial gains are made early in practice. In mathematical terms, the power law of practice is given by

$$RT = a + bP^{-c}$$

where RT represents response time, a is the asymptotic RT, b is the difference in performance time on the first and last trial, P represents the number of practice trials, and c represents the learning rate parameter that specifies how quickly RTs reach asymptote (Palmeri, 1999). According to Anderson (1982), Logan (1992), and Newell and Rosenbloom (1981), the asymptote is an important feature of the power function as it represents the theoretical minimum level of performance that is limited by cognitive or mechanical factors (Anderson, 1982; Logan, 1992; Newell and Rosenbloom, 1981). It has been assumed that when the asymptote level is reached, no further improvement in skill performance occurs

because no further learning occurs. Figure 1 depicts the typical trend of power function learning.
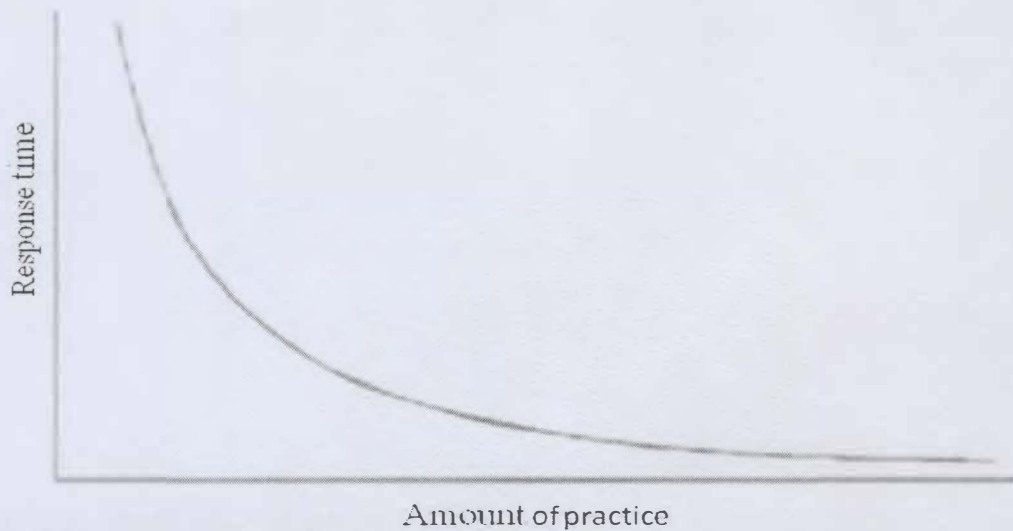
Figure 1. A representation of power function learning

Power learning curves have been found to occur across various task domains such as cigar manufacturing and maze solving (Crossman, 1959), the search for visual targets (Neisser, Novick, & Lazar, 1963), fact retrieval (Pirolli & Anderson, 1985), sentence repetition, evaluation of logic circuits, geometry proof solution (Newell & Rosenbloom, 1981; Rickard, 1997) and concentration tests (Hagemeister, 2007). According to Palmeri (1999), it was suggested to be one of the most ubiquitous findings in experimental psychology (Palmeri, 1999). The support for the power law of practice has been so strong that it is often regarded as a psychological law and it has had tremendous influence on the development of many skill acquisition theories (e.g., Anderson, 1993; Anderson, Fincham, & Douglass, 1999; Frensch, 1991; Hagemeister, 2007; Logan, 1988; Newell & Rosenbloom, 1981; Palmeri, 1997; Rickard, 1999. Speelman & Kirsner, 2001) and theories of automaticity (e.g., Anderson, 1982, 1987, 1992; Cohen, Dunbar, & McClelland, 1990; Ericsson, Krampe, & Teschromer, 1993; Logan, 1988, 1992; MacKay, 1982; Nosofsky & Palmeri, 1997; Palmeri, 1997; Rickard, 1997).

Automaticity

Automaticity is an important phenomenon in skill acquisition (Logan, 1988). The instance theory of automaticity postulated that performance is automatic when solutions from memory are directly-accessible and performance requires only a single step. This automatisation is reflected by a transition from performance based on some general algorithm for performing the task to performance based on memory retrieval (Logan, 1992). Automatic processing will occur only after practice in a consistent environment as stimuli are mapped consistently to the same responses throughout practice (Logan, 1988). However, if the participants do not have any prior experience in solving a task, they will solve the problem by applying a general algorithm. These solutions are then encoded into memory and would be retrieved when the same problems are encountered again. Performance will become automatic in that problems can be solved by memory retrieval when sufficient practice has occurred (Logan, 1992). However, skill acquisition goes through three stages of development which will be described by Fitts and Posner (1976).

Fitts and Posner's three stages of development

Skills are acquired through a process of learning. This process is described by Fitts and Posner (1967) who suggested that skill acquisition involved three stages of development. The cognitive stage is first. This stage involves an initial encoding of skill into a form that is sufficient to generate a desired behaviour. During this stage, a beginning performer is trying to understand the task, and performance is slow, deliberate, and errorful. The performer comes to terms with instructions and develops performance strategies. According to Fitts and Posner, these strategies develop from general 'sets' and strategies developed with previously learned tasks. Performance becomes more accurate, patterns of performance elements begin to emerge, and gross errors are eliminated in the second associative stage. Previously learned strategies that are relevant to the new situation are strengthened on the basis of feedback

while the irrelevant strategies are weakened. Lastly, in the autonomous stage, task performance is often more reliable, efficient, fluent, and less likely to break down under stress. As components of the performance strategy gradually become more autonomous, performers are less subjected to cognitive control or external interference. The performance of the skill continues to improve as this stage progresses. However, the rate of improvement slows with practice (Anderson, 1982; Groeger & Banks, 2007; Speelman & Kirsner, 2005). This is congruent with the power law of learning where substantial gains are made early in practice and there are diminishing marginal gains with increased practice.

A study by Adu-Japha, Karni, Parnes, Loewenschuss, and Vakil (2008) on the acquisition of motor skill supports the power law of learning. Seventeen psychology students (4 men), age ranging from 19 to 26 years, all right handed, took part in the study as part of their first year duties. None had history of neurological or musculoskeletal disorder or of medication use. Participants of the study were required to complete a computerized task where they were instructed to repeatedly type a five-movement sequence with four fingers (thumb excluded) of their right hand in a cued manner. The sequences were analysed in terms of speed and accuracy measured by number of sequencing errors. The results of the study indicated that after an initial improvement in speed and decrease in variability, there was a significant increase in variability in performance without a change in mean performance speed. Subsequently, as practice continued, variability once again decreased and there was a great significant increase in performance. The type of errors committed decreased and performance became more coherent. This study provides an example of how skills are acquired according to the power law of learning where with practice, performance improved.

Anderson's ACT theory

Anderson's ACT theory has described skill acquisition as a three-stage process that loosely corresponds to Fitts and Posner's model of skill acquisition. Anderson ACT theory

(Anderson, 1982, 1983, 1987, 1992) demonstrat the development of specific and general skills. His theory posited that skills are more general, illustrating how they can apply to situations previously encountered as well as being generalisable to new tasks that share some similarity with previous tasks (Anderson, 1982; Anderson, 1983; Anderson, 1987; Anderson, 1992). In the early phase of skill acquisition under the Fitts and Posner model of skill acquisition, the ACT theory corresponds to the application of general problem-solving methods to declarative knowledge and initial development of production. A production rule transforms the current problem state into an action solution by operating on the facts stored in declarative memory such as an analogy applied to a previous experience or an explicit task-related instruction. Fitts and Posner described this phase as the cognitive stage where processing of the task is performed while Anderson (1983a) claims this stage to involve the interpretive applications of knowledge (Speelman & Kirsner, 2005). Performance in this stage is error-prone and slow as working memory resources are utilised by the interpretation of declarative knowledge (Ackerman, 1988).

Fitt and Posner's intermediate phase, also known as the associative phase, is explained by the ACT theory's compilation process. That is, it describes the formation of specific associations between stimulus cues and appropriate responses. These compilations of declarative knowledge become production rules that are stored in procedural memory. This stage corresponds to the reduction in number of steps (productions) required to perform a task hence reducing working memory load. As memory load is reduced, performance often becomes faster. Performance at this stage relies on productions that are stored in procedural memory as well as the activation of prior experience (Blessing & Anderson, 1996). The final phase of Fitts and Posner's theory is explained by the ACT theory's strengthening process. It is the stage where processing becomes increasingly autonomous with increased practice as skills are less reliant on working memory resources (Speelman & Kirsner, 2005). With each

successful application, production rules accumulate strength. The stronger a production is, the faster the retrieval and execution (Anderson, 1992). Therefore, the combination of compilations and strengthening results in a speed-up of performance that proceeds with practice (Speelman & Kirsner, 2005). Anderson (1982) has demonstrated that the three stages contained in his ACT theory can account for the power law of learning which is evident in the present study.

Logan's Instance Theory

A second fundamental theory of skill acquisition is Logan's (1988, 1990, 1995, 1998, 2002) instance theory. Logan's instance theory depends on two mechanisms: an algorithmic response to the solution, or retrieval of past solutions from memory (Logan, 1988). Initially, skills require the execution of an algorithm (Hoyer, Cerella, & Onyper, 2003). When an algorithm is performed successfully each time, the event is represented in memory as an instance (Logan, 1988). With increased practice, there is a strategy shift to direct memory retrieval when the stimuli are represented (Bajie & Rickard, 2009; Delaney, Reder, Staszewski, & Ritter, 1998; Haider & Frensch, 2002; Logan, 1988; Rickard, 1997). The number of instances related to a task increases with practice. At the same time, the speed of retrieval becomes faster when there are an increased number of instances stored in memory (Bajie & Rickard, 2009; Logan, 1992). Thus, practice leads to a reduction in performance time (Logan, 1988). Logan (1988) indicated that the reduction in performance time conforms to the power law of learning where performance is a power function of the amount of practice (Logan, 1988). That is, as more instances are added into memory, there would be diminishing returns such that performance gets faster. This produces a negative acceleration that is the characteristic of power functions (Logan, 1990).

Although theories of Anderson and Logan have been discussed on how skill acquisition occurs, the main aim focus of this experiment is the transfer of skilled

performance to a different task or situation. That is, how much of the skills acquired in training may be utilised in another domain without much disruption in the performance time. There has been much inquiry and debate as to how these developed skills can be applied to other domains (e.g., Anderson, 1993; Doane, Sohn, & Schreiber, 1999; Fraser, Peets, Walker, Tworek, Paget, Wright, & McLaughlin, 2009; Logan, 1988; Rickard, Healy, & Bourne, 1994; Palmeri, 1997; Speelman & Kirsner, 2001; Strum, Windsor, Cosman, Cregan, Hewett, & Maddern, 2008). The next part of this paper discusses how skills can be transferred to other domains.

Skill Transfer

Given the underlying explanations of how skills are acquired, both Logan and Anderson give specific predictions regarding the transfer of such skills. Transfer of training is the learning of a response in one situation that can be transferred successfully to a broader range of circumstances (Adams, 1987; Groeger & Banks, 2007). According to Anderson's (1982) ACT theory, the extent of transfer is influenced by the extent to which productions developed in the context of one task can be utilised in performance of the other task. Greater production overlap results in greater transfer (Anderson, 1982). There has been some empirical support in studies (e.g., Elio, 1986; Frensch, 1991; Kieras & Bovair, 1986; Singley & Anderson, 1989) for this theoretical perspective where transfer is predicted on the basis of an analysis of the production rules acquired during training and the production rules necessary for performance of a transfer task (Speelman & Kirsner, 2001). Transfer of skills has been demonstrated in several studies such as lexical decision tasks (Kirsner & Speelman, 1996), syllogisms (Speelman & Kirsner, 1997), basic arithmetic skills (Rickard, Healy, & Bourne, 1994), letter search (Schneider & Fisk, 1984), role of processing strategies (Doane, Sohn, & Schreiber, 1999), and transfer of knowledge in a multistep serial task (Frensch, 1991).

The type of knowledge acquired during task practice moderates transfer therefore it is important to consider the type of knowledge that is acquired. In the literature of skill acquisition, there were two theories that were mentioned earlier. It was Logan's instance theory, that states that skilled performance involves the acquisition of domain-specific knowledge (e.g., Logan, 1988) and Anderson's ACT theory, that proposes that skilled performance involves the development of domain-general knowledge (e.g., Anderson, 1993). Domain-specific knowledge means that performance of a learned skill on a transfer test tends to be specific to the actual items that have been practiced (Healy, Wohldmann, Parker, & Bourne, 2006). That is, skill acquisition is a result of the connections between a specific stimulus and its response being strengthened by continuous exposure to the same stimulus in the experienced event. Conversely, domain-general knowledge is a combination of domain-specific knowledge and domain-general processing knowledge (Anderson, 1993; Speelman & Kirsner, 1997). Domain-general processing suggests that skills acquired during practice may be applied to a broader range of circumstances that were not previously encountered through practice. According to Doane, Sohn, and Schreiber (1999), domain-general processing is not bounded by a particular stimulus performed during training but a strategic processing skill that has been acquired from exposure to the stimuli (Doane, Sohn, & Schreiber, 1999).

Logan's Instance theory

Logan (1988) posited that because the acquisition of skills lies in specific memories for previous instances, instance theory predicts extremely narrow transfer of cognitive skills to novel situations (Logan, 1988). The Instance theory states that performance is based on the retrieval from memory of a specific response to a specific stimulus (Logan, 1988; Palmeri, 1997; Rickard, 1999). Therefore, skill transfer is considered stimulus-specific. However, according to the instance theory, instances are retrieved in their entirety, which means that transfer can only occur between identical tasks. When a new task is encountered, there will

be no instances in memory and performance requires the application of an algorithm and performance would return to prior practice levels.

Several studies (e.g., Healy, Wohldmann, Parker, & Bourne, 2005; Healy, Wohldmann, Sutton, & Bourne, 2006; Lassaline & Logan, 1993; Wohldmann & Healy, 2010) have demonstrated how training can lead to specific knowledge. These can be seen as derived from Thorndike's (1906) theory of identical elements of transfer. These researchers have agreed that skill transfer performance under the specificity condition often demonstrated a lack of ability to generalize beyond the situations presented during training. Skill specificity has been demonstrated in a variety of tasks. Lasting specificity of training effects have been observed in the Stroop task (Clawson, King, Healy, & Ericsson, 1995). Participants were trained to name the words and ignore the colours. Results of the study indicated that participants were faster on the specified trained colour set of words than an untrained set (Clawson, King, Healy, & Ericsson, 1995). Another study by Rickard, Healy, and Bourne (1994), where participants were trained on a mental calculation task, suggested that the effects of training on the mental calculation task were highly specific to the trained problems. Performance was faster on problems actually practiced than on totally new problems and faster on practiced problems than on similar problems (Rickard, Healy, & Bourne, 1994). These studies have supported Logan's instance theory that no transfer would occur between tasks that were not identical to training. These studies also suggested that no matter how good performance was in the training phase, the participants were unable to transfer their skills to a new phase if the stimuli presented were not similar, hence, disruption occurred.

Anderson ACT theory

Recognising production rules as elements of knowledge accounting for transfer was possible through the revival of the identical elements theory (Anderson, 1987; Anderson & Singley, 1993, & Anderson, 1989). Anderson's ACT theory is different from Logan's

Instance theory such that in Anderson's theory, the amount of transfer that occurs can be accounted for by the number of shared productions two tasks shared. As described above, these productions are formed based on the by-product of comparing two declarative representations. A comparison is done and common features are extracted between the current and previous representations. There are generally three different types of transfer; positive, partial and zero transfer. With regards to the present study, we are only interested if complete transfer occurred. Complete transfer is suggested to have occurred if performance on a transfer task, once plotted, continues in line with the prediction of the training learning curve (Speelman & Kirsner, 2005). That is, a reduction in total time performance and errors should be observed. According to Singley and Anderson (1985), transfer which is based on overlap of production sets leads to a two-component model. The first component is the intersection of two production sets while the second component, the specific component is the remainder of a particular set. When there is a high level of transfer (e.g, positive transfer from the training to transfer phase), transfer may be explained in terms of performance in prior trials as the general component has overshadowed the specific component (Singley & Anderson, 1985). The level of transfer is relevant to the current study where we would like to explain transfer performance with reference to prior trials. That is, with good performance in the trials prior to transfer, are we able to predict if transfer performance continue to improve like the training power learning curve.

In summary, several studies indicated that with practice, skills were being transferred either to a situation identical or a novel situation where retrieval of productions formed as according to Anderson's ACT theory was applied together with prior experience. The present study utilised Anderson ACT theory to investigate if performance in the transfer phase would continue to improve according to the learning curve from the prior phase of training as the stimuli between the transfer and training phase is slightly different.

Purpose

An enduring problem in psychology has been the issue of transfer of learning (Blume, Ford, Baldwin, & Huang, 2009). The purpose of the proposed quantitative study was to further investigate Speelman and Kirsner's (1993, 2001; Speelman, 1995) approach to predicting transfer performance in new tasks based on the power function that described training performance. Speelman and Kirsner's (2001) study was designed to investigate the rationale of both the ACT and Instance theory that the performance of old skills will continue in line with the power law of learning in a new task (Anderson, 1993; Logan, 1988).

Speelman and Kirsner's (2001) study required participants to perform several arithmetic calculations to assess water purity. Response time was noted but not accuracy. The aim of the experiment was to investigate whether the performance of the old calculations would be disrupted in the transfer phase despite much practice in the training phase or would these old skills continue to improve in the transfer phase as they had always been performed in the training phase. There was a training phase and transfer phase in which the number of calculations would vary. The training phase required three simple arithmetic calculations while the transfer phase contained the same three simple arithmetic calculations and an additional two components. This totalled to five simple arithmetic calculations. The two versions of the test are presented in Figure 2. As the experiment was only interested in measuring performance on the three identical arithmetic calculations in the transfer phase, the additional two components should not have an effect on performance of those three calculations. According to Anderson's ACT theory and Logan's Instance theory, as the exact components were being utilised and measured, the productions and processes employed and the instances created during training should have resulted in complete transfer in the transfer phase on those three old calculations. At the same time, as the same productions and instances can be executed in the training and transfer tasks, the speed of execution of the old

calculations in the transfer phase should be predicted by extrapolating the training power

functions.

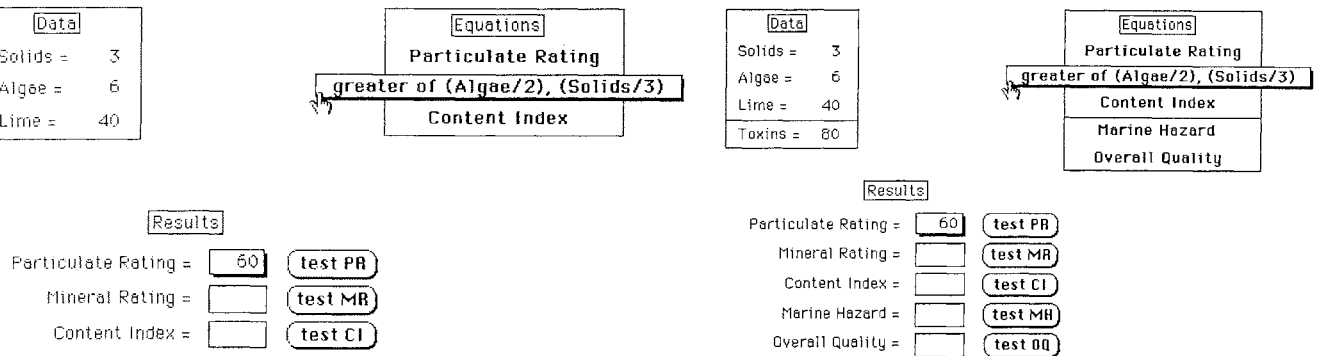Training Task   Transfer Task

Data	
Solids =	3
Algae =	6
Lime =	40

Equations
Particulate Rating
greater of (Algae/2), (Solids/3)
Content Index

Data	
Solids =	3
Algae =	6
Lime =	40
Toxins =	80

Equations
Particulate Rating
greater of (Algae/2), (Solids/3)
Content Index
Marine Hazard
Overall Quality

Results		
Particulate Rating =	60	(test PR)
Mineral Rating =		(test MR)
Content Index =		(test CI)

Results		
Particulate Rating =	60	(test PR)
Mineral Rating =		(test MR)
Content Index =		(test CI)
Marine Hazard =		(test MH)
Overall Quality =		(test OQ)

Figure 2. Speelman and Kisner's three component task (training phase) and five component

task (transfer phase).

The results of the study revealed that there was disruption in the expected transfer

performance. The results are presented in Figure 3. Speelman and Kirsner found that

performance in the transfer phase on the identical three components were performed slower

than at the end of training. Although the three components were identical, the presence of the

additional two novel components affected the performance time. The study had failed to

support both Anderson and Logan's account of transfer performance since these accounts

would predict complete transfer of the identical components in the novel task. As the training

literature in general has supported the fact that learning in training does not automatically

result in transfer (Roberson, Kulik, & Pepper, 2009), the current study investigated if the

amount of training given is sufficient for the participants to have acquired enough knowledge

for performance in the transfer task and if enough training would allow the prediction of

transfer. Research has also suggested that unless there is an improvement in performance in

the transfer phase, skills acquired in training phase have not been transferred (Valeda,

Caetano, Michel, Lyons, & Kavanagh, 2007). That is, performance in the transfer phase

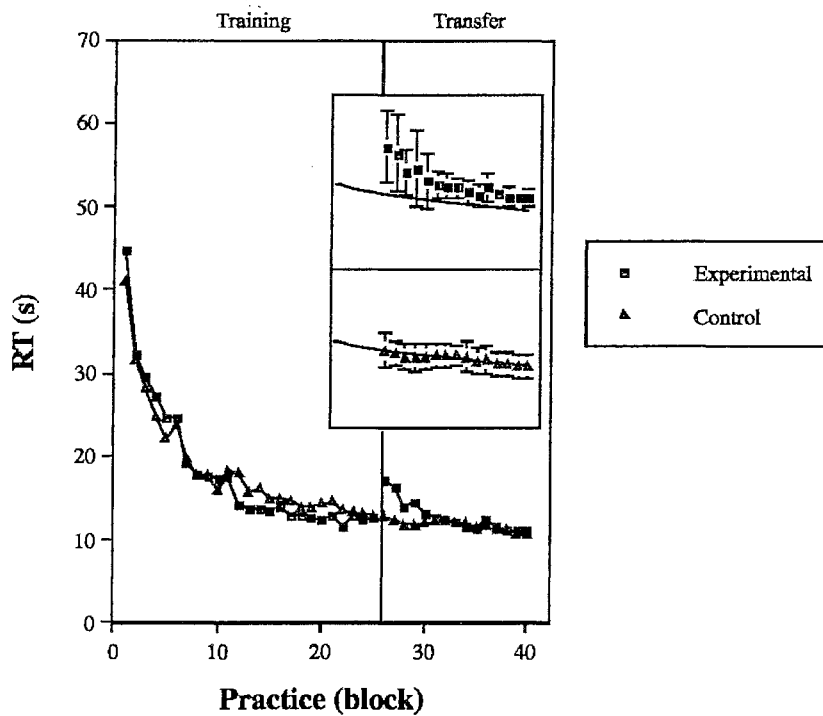should be an extrapolation of the learning curve.

Figure 3. Results of Speelman and Kirsner (2001) study indicating that transfer had failed to

occur.

Overview of the experiment

The current study, like Speelman and Kirsner's (2001) experiment, involves training

and transfer phases, and examines performance on an identical test task in both phases. The

transfer phase consisted of the test task and an altered version of the test task (i.e., a distractor

task). An examination of performance on the test task between the training and transfer

phases was carried out to determine whether transfer was disrupted as a consequence of

introducing the distractor task.

The present study consists of a simple counting task. It was similar to Lassaline and

Logan's (1993) study of dot counting. Performance of these tasks was considered to be well

established and reliant on memory retrieval and executing of algorithms (Campbell, 1999;

Lassaline & Logan, 1993; Siegler, 1988). Participants were required to count the number of

stars presented to them. Test items used in this study were the number of black stars present

whereas the distractor tasks were an altered version of the test stars which consisted of black and red stars. The methodology of this present study incorporated the findings of Speelman and Kirsner (2001) where they investigated the transfer of learning from a simple calculation task.

The present study manipulated amount of training participants received to investigate if the amount of training would affect performance in the transfer phase despite experiencing the old stimuli from the training phase. Groups of stars were presented and participants were required to evaluate if there was an odd or an even number of stars. This star counting task was repeated through the training phase. During the transfer phase of the present experiment, participants were presented with the same items, along with a set of distractor items. After participants responded to an old item on a transfer trial, the red stars were then added to the display, and participants were then required to respond odd or even again. Introducing a distractor task in this way enabled measurement of performance on the old task in the context of a new task. It was then possible to measure the extent to which the test task disrupted transfer to the old task.

Experiment predictions

The assumption of this study was that transfer predictions could be made on the basis of power functions that describe training performance. That is, old skills were expected to continue to improve in the context of a novel situation according to the power function that described their improvement during the training task. Studies by Speelman and Kirsner (2001), and Speelman and Kirsner (1993) have indicated that any discrepancies in the data between observed and predicted performance indicated the extent to which transfer had occurred and this approach has been utilized in studies that investigate skill transfer performance (Speelman & Kirsner, 2001; Speelman & Kirsner, 1993). The assumption that amount of training investigating transfer will be supported if it follows the learning curve

from training task to transfer task. That is, with more practice, reaction time decreases and performance of the old skills should continue to improve in new tasks. This prediction is congruent to Singley and Anderson (1985) two-component model that when there is a high level of transfer from training to the transfer phase, this transfer may be explained in terms of performance in prior trials. In this particular experiment, Singley and Anderson (1985) model would be supported if performance in prior trials could predict the amount of transfer disruption where good performance would result in less disruption occurring. Good performance was defined as a reduction in performance time and increase in accuracy. It was defined as such as high performance threshold usually leads to high accuracy and high reaction time, whereas low performance threshold usually leads to low reaction time and low accuracy (Forstmann, Dutilh, Brown, Neumann, von Cramon, Ridderinkhof, & Wagenmakers, 2008).

Method

Participants

Before the recruitment of participants, the study was submitted to Human Research Ethics Committee for approval. Once the study had gained approval, recruitment of participants began. The participants were recruited through posters put up around the school, going into lecture theatres seeking for volunteers, as well as friends who studied in the University. A total of 60 students from Edith Cowan University volunteered to participate in the experiment. The participants were aged 18 to 50 years of age. The 60 students who volunteered were randomly assigned to one of the three conditions where there were 20 participants per group. The first condition consisted of 10 blocks of 8 trials each and 2 blocks of 8 transfer trials each. The second condition had 20 blocks of 8 trials each and 2 blocks of 8 transfer trials each, and lastly, the third condition made up of 30 blocks of 8 trials each and 2

blocks of 8 transfer trials each. However, due to a computing error, participants in the 20

blocks of 8 trials could not be used.

Materials

A computer with a separate response pad was used to present the test conditions and

record participant responses. Presentation of the experimental task and data collection were

controlled by SuperLab 4.0 software.

Stimuli

The experiment used stars as the stimulus items. A sample of these items is presented

in Figure 4 (see Appendix A for the complete set of items). The selection of the stimulus

items were based on Lassaline and Logan's (1993) study of dot counting. The stimulus in the

training phase included a total of 6 to 13 stars. The transfer phase consisted of the same 6 to

13 stars and had additional start varying from 1 to 4 added to it. The items used in the

example below indicated that the training phase consisted of 8 black stars. The items used in

the transfer phase consisted of 8 black stars which were identical to the training phase and 3

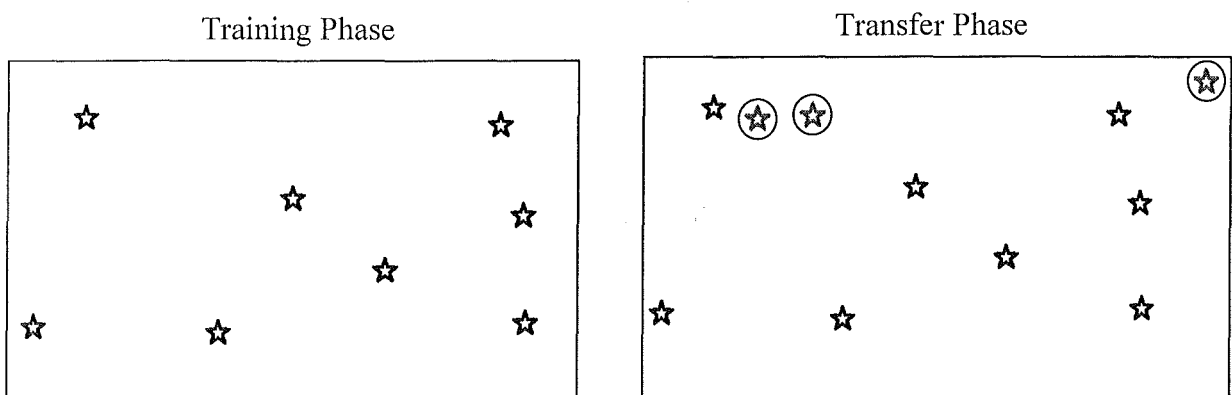additional red stars which served as a distractor. These items were presented in Figure 4.

Training Phase   Transfer Phase

Figure 4. Sample of items used in training and transfer. Stars in circles were presented in red

during the transfer phase.

Design

A between-subject design was used in this study. The amount of practice was the independent variable. There was a training phase and a transfer phase, with all participants completing both phases. Participants were randomly assigned to one of the three conditions, where some performed 10 blocks of trials in training, whereas others performed 20 blocks, or 30 blocks. Each condition consisted of 20 participants. There were two dependent variables: reaction time and accuracy. Reaction time was measured in milliseconds and accuracy was assessed as the number of correct responses. As the focus of the study was based on performance of the test tasks, a between subject design was used to assess any disruption effects on test task performance at transfer for each condition. At the same time, a within-subjects comparison was used on performance between the training and transfer phase to investigate the effect of task transfer.

Training phase. In training, 8 stimuli were presented, repeatedly, in a random order. Each stimulus consisted of stars on the screen ranging from 6 to 13 stars (see Appendix A for an example stimulus). Participants were required to indicate whether each stimulus depicted an odd or an even number of stars. They were to respond using the response pad. Each block of 8 stimuli were repeated in different random orders, for as often as the training condition dictated (i.e., 10, 20, or 30 times). The stars that were presented were black in colour. A total of 80 test trials were completed for the block of 10, 160 for the block of 20, and 240 for the block of 30.

Transfer phase. Similar to the training phase, the transfer phase included a combination of both the 8 stimuli presented in the training phase and another 8 set of new stimuli. The new set of stimuli consisted of black and red stars. The presentation order of

stimuli was random within blocks. However, participants were first presented with a screen of black stars which is the test stimulus and after responding, they were presented with the same screen of black stars with additional red stars which is the transfer stimulus (See Appendix B for example stimulus). Again, they were required to indicate if there was an odd or even number of stars.

Task and Procedure

The task involved a simple counting task which was similar to Lassaline and Logan's (1993) study of dot counting. Participants were tested individually. They were seated in a private room in front of a computer screen and response pad and were instructed to read the instructions, information sheet, and to complete a consent form before commencing (see Appendix C). They were asked if they had any queries before commencing the experiment. Once this was completed, participants were allocated to one of the three conditions and the researcher left the room. Participants were advised to continue until the completion of the trials. The instruction sheet that was provided explained the procedure of the experiment whereas the information sheet indicated the purpose of the experiment.

Two versions of the task were developed. Participants performed with one version during the training phase of the experiment and the other during the transfer phase. The main difference between the two tasks was the number of trials present in each block. There were 8 trials per block in the training phase. In the transfer phase, there were 8 trials per block, but each trial had 2 parts to it. The first part consisted of the identical 8 trials that were present in the training phase, whereas the other 8 trials were slightly different from the training phase. In all other respects, the training and transfer phase were identical. Response and accuracy were measured at each stage during a trial.

At the beginning of the experiment, a screen labelled "ready" was presented on the screen. When the participants were ready, they were required to press a button labelled "ready" to commence the test. Once the participants had pressed the "ready" key on the response pad, the training phase of the experiment commences. This included 80 trials for the 10 block condition, 160 trials for the 20 block condition, and 240 trials for the 30 block condition. The presentation of the trials was in a random order. Immediately following the completion of the training phase, the transfer phase commenced. The participants were not alerted to this change. The presentation of stimuli in the transfer trial was such that the test stimuli and distractor stimuli were presented consecutively but the rest of the trials were in random order. Participants were not provided with feedback as to whether their response was correct or incorrect.

Results

Performance on the tasks was analysed in blocks of 8 trials. In one condition, there was 10 blocks of trials in the training phase while the other condition had 30 blocks of trials. Both conditions had 2 blocks in the transfer phase consisting of 8 trials in each block. In the training phase, the 10 blocks and 30 blocks of trials consisted of test items. In the transfer phase, the 2 blocks of trials consisted of 8 trials of test items and 8 trials of distractor items. The order of representation was such that the test items were presented directly before the distractor items. In the transfer phase, analysis focused on performance in the first part of each trial. For the purpose of the analysis, response time and accuracy were recorded. Accuracy was defined as the number of correct calculations in a block. When deciding whether to use an individual participant's data, accuracy was assessed as the number of correct trials in the entire training phase. Only correct responses were included in the response time analyses. Participants who did not maintain an accuracy level of 100% in the

training or transfer phase will be eliminated from the analyses. Response time was defined as the time elapsed in milliseconds between the presentation of an item and the participant's response on the response pad that identified their answer. Participants who had response time of above 20000 milliseconds and below 100 milliseconds were excluded from the analyses. All analyses were performed using SPSS and Excel software programs.

To examine the various relationships between performance in training and transfer, independent t-tests analyses was conducted. In each of the analyses, amount of training was added as an independent variable while reaction time and accuracy as well as RT/ACC which denotes performance were the dependent variables. If significance was found between the amount of training and the different groups, it indicated that with more practice, performance improves. To further investigate if there was a relationship between good performance (RT/ACC) and amount of disruption, a Pearson correlation was conducted. If there was a positive correlation between the good performance and amount of disruption, results would indicate that with more practice, there was more disruption.

For each participant, a mean reaction time was calculated for each block of trials. Overall mean reaction time and accuracy for each block across all participants was calculated. Good performance was denoted by RT/ACC and this was calculated as well. This was done for the 10 blocks and 30 blocks of trials in the training and transfer phase. However, in the transfer phase, only the first part of the trial was taken into consideration.

Training

Accuracy

Performance accuracy remained high throughout experimental trials. The combined mean accuracy in the training and transfer phase is presented in Figure 5. To determine whether there was a difference in performance accuracy on the test task between the 10 blocks and 30 blocks, an independent-sample t-test were performed on the accuracy for the

last block of training phase. The analyses revealed that there was no significant difference in accuracy between the conditions of 10 ($M = 7.75$, $SD = .55$) and 30 ($M = 7.60$, $SD = .50$) blocks at the end of the training phase, $t(38) = .900$, $p > .05$.
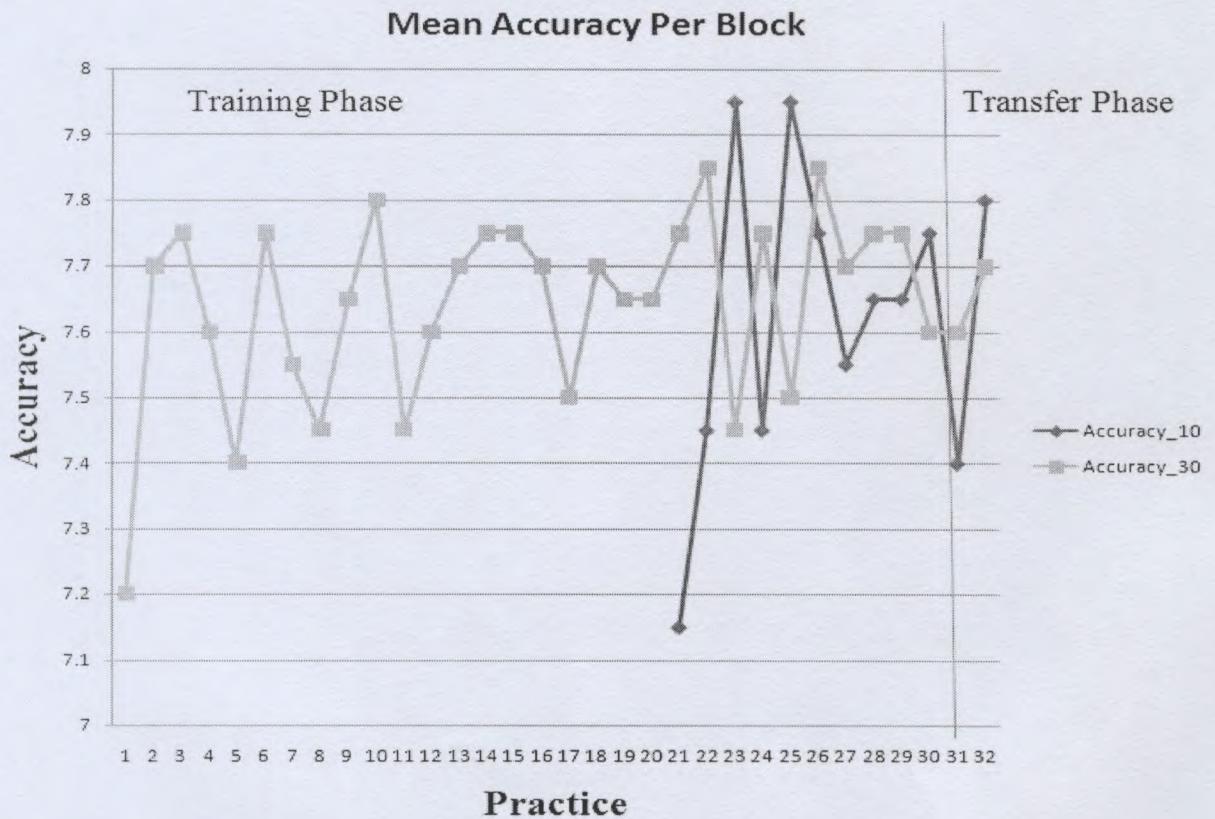

Figure 5. Mean accuracy for all participants across training and transfer phase

Response time

Overall mean reaction time was plotted against practice. Figure 6 gives an illustration of the overall reaction time for all participants across training. However, in the study, only the reaction time in the last block of training in both conditions was of much interest. It was to investigate whether reaction time in the last block of training before transfer would extrapolate the learning curve in transfer conditions despite the change in task. Reaction time for performance was compared between the condition of 10 and 30 blocks of trials. To examine if a comparison between the participants reaction time between the two block conditions were significant, an independent-sample t-test was conducted. The results revealed

that reaction time in condition block 30 (M = 2697.07 milliseconds, SD = 611.16 milliseconds) was significantly faster than condition block 10 (M = 3222.85 milliseconds, SD = 840.16 milliseconds), $t(38)$ = 2.26, $p < .05$.
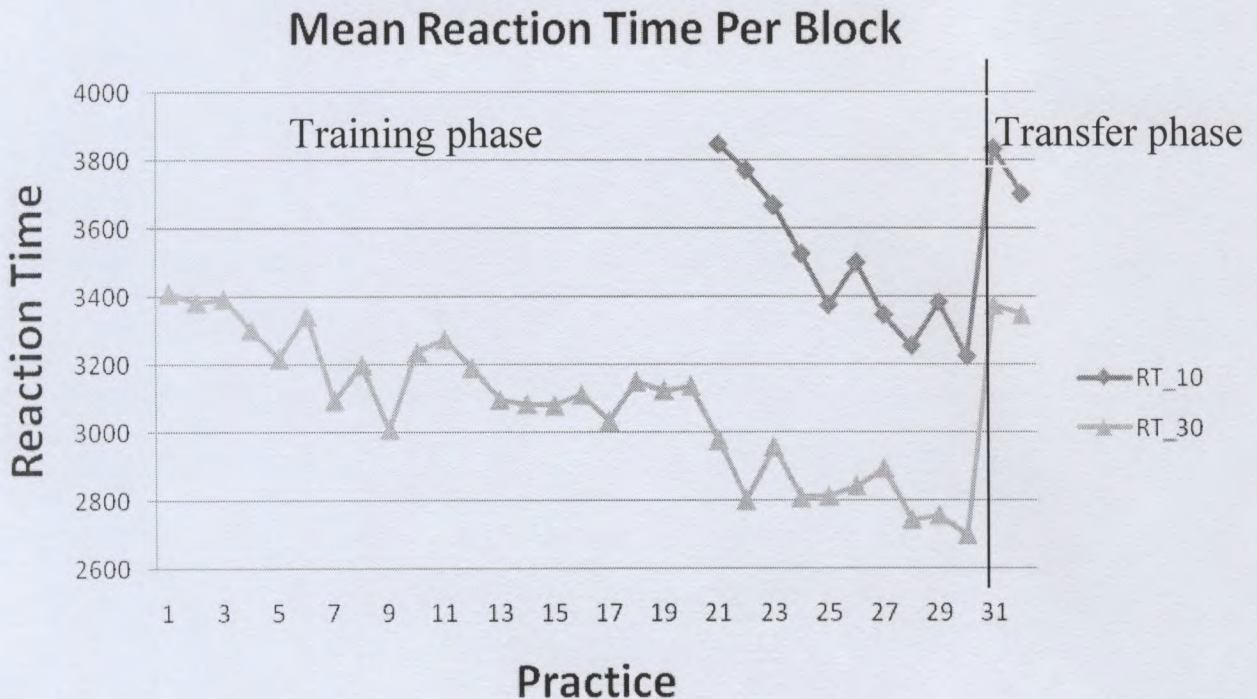
Mean Reaction Time Per Block

Figure 6. Mean reaction time for all participants across training and transfer phase

RT/ACC

Taken together, RT/ACC denotes good performance. Good performance was defined as having a low RT and high ACC. RT/ACC was examined in the last block of training for both conditions before transfer. An independent-samples t-test was used to investigate whether good performance would reduce transfer disruption. Results of the independent-sample t-test revealed that there was a significant difference in performance, as measured by RT/ACC between the 10 blocks (M = 419.66 milliseconds, SD = 117.6 milliseconds) and 30 blocks (M = 354.44 milliseconds, SD = 75.92 milliseconds), $t(32.48)$ = 2.08, $p < .05$. Performance in the condition of 30 blocks was better as compared to performance in the condition of 10 blocks. This indicated that with more practice, performance improves.

10th block in both conditions

As amount of training was manipulated in this study and both conditions had different amounts of training, a comparison between the 10th block of training in both conditions was carried out. An independent-sample t-test investigating the response time, accuracy, and RT/ACC which denotes good performance, was conducted. Results revealed that for reaction time in the 10th block, although the block 10 condition (M = 3222.85 milliseconds, SD = 840.16 milliseconds) was slightly faster than the block 30 condition (M = 3235.81 milliseconds, SD = 432.25 milliseconds), there was no significant difference between the 2 conditions, $t(28.4)$ = -.061, p > .05. The test was also conducted on accuracy and there was no significant difference between the block 30 condition (M = 7.80, SD = .41), and the block 10 condition (M = 7.75, SD = .55), $t(38)$ = -.326, p > .05. Lastly, a t-test was conducted to examine the difference in RT/ACC between the 2 conditions in block 10. There was no significant difference between the block 10 condition (M = 419.66 milliseconds, SD = 117.68 milliseconds) and the block 30 condition (M = 416.88 milliseconds, SD = 68.07 milliseconds), $t(30.43)$ = .092, p > .05.

Transfer

Transfer disruption

An independent-sample t-test was conducted between the two conditions to examine if there was a significant difference in the amount of transfer disruption. The results revealed there was no significant difference between the 2 conditions, where the block 10 condition (M = 611.55 milliseconds, SD = 640.89 milliseconds) was as equally disrupted as the block 30 condition (M = 676.67 milliseconds, SD = 520.50 milliseconds), $t(38)$ = -.353, p > .05. Further analysis was conducted to investigate the hypothesis of whether RT/ACC was able to predict transfer disruption. Pearson correlation was conducted and results indicated that there was a positive correlation between good performance (RT/ACC) and high transfer disruption,

$r = .331$, $p < .05$ indicated that as performance in training gets better, the amount of transfer disruption increases.

Transfer recovery

As with practice, performance was suggested to improve following the transfer disruption. An analysis on reaction time was conducted to examine if there was a significant difference between the improvements occurring between the second block of transfer and the first block of transfer for the two conditions. An independent-sample t-test was conducted and results indicated that the block 30 condition ($M = 28.11$ milliseconds, $SD = 611.50$ milliseconds) had a smaller difference in performance recovery between the second and first block of transfer than the block 10 condition ($M = 129.41$ milliseconds, $SD = 969.21$ milliseconds). However, there was still no significant difference noted between the two conditions $t(38) = .395$, $p > .05$.

Discussion

The main aim of the present study was conducted to extend previous literature that has researched expansively on how transfer performance could be predicted on the basis of training performance as described by Speelman and Kirsner (2001). That is, whether good performance in training which was denoted by RT/ACC, could predict the amount of disruption that would occur in transfer performance. A basic assumption underlying this prediction was that old skills executed in the context of a new task would continue to improve as if stimulus condition has not altered. During the transfer phase, participants performed the same 8 trials that they had performed in the training phase. However, the 8 trials presented now have two parts to it and what was first presented was the identical stimulus shown in training followed by a slightly different stimulus. The results indicated, that in comparison with the two phases where participants performed the exact same 8 trials, the transfer phase revealed a slowing in performance on the "old" skill. As there was the 10 block condition and

30 block condition, the results indicating a slowing in performance in the transfer phase was greater in the 30 block condition. However, reaction time in the last block of training was relatively faster in the 30 block condition as compared to the 10 block condition. The results have failed to support the hypothesis that good performance in training could predict the amount of disruption that would occur in transfer. That is, with more practice, one would have experienced less disruption while transferring to a novel task. The hypothesis was not supported because during the last block of training, the block 30 condition demonstrated a faster reaction time as compared to the other condition but had demonstrated a higher level of disruption during transfer. Although the hypothesis was not supported, the results have provided support for the assumption of Speelman and Kirsner (2001) study that alterations in task conditions have had an effect on skill performance but not on skill improvement.

Response time and Performance

The ability to extrapolate power functions that describe training performance in order to predict later performance was only evident in the training phase. Results indicate that with more practice, participants skills improved and response time grew significantly faster. This result suggests that extended training does equip an individual with the opportunity to improve their skills by developing instances or productions as posited by Logan's Instance theory (1988) and Anderson's ACT theory (1987). With more instances and productions, response times became significantly faster. This result is predicted by the power law of learning (Newell & Rosenbloom, 1981) and has been supported in several studies. These studies include a lexical decision task (Kirsner & Speelman, 1996), a fictional water analysis task (Speelman & Kirsner, 2001), a dot counting task (Lassaline & Logan, 1993), alphabet arithmetic (Brewer, 1998; Logan & Klapp, 1991; Piani, 1998), fact recognition (Pirolli & Anderson, 1985), and Shute and Gawlick (1995) study on flight engineering knowledge and skills.

In contrast, using the same method to predict performance from the training phase to the transfer phase was unsuccessful. Results of the study in both conditions indicated an increase in reaction time when there was a change in task. This slowing of performance with the change in task indicated that transfer response times were underestimated by extrapolating the training performance. This meant that when old skills were performed in the context of a new task, performance did not improve according to the power function that demonstrated the initial improvement. This indicated that transfer disruption had occurred. This finding was consistent with Speelman and Kirsner's (2001) study that a change in the conceptual environment was sufficient to affect performance on an established skill.

Contextual change

Speelman and Kirsner (2001) posited that when the task conditions in which an established skill was performed had changed, transfer disruption would occur. This finding was consistent with the 10 block and 30 block conditions. Speelman and Kirsner (2001) predicted that initial disruption would be greatest when contextual change was greatest. The factor that might have attributed to a greater transfer disruption with participants in the 30 block condition as compared to the 10 block condition is contextual change. This can be explained with regards to the fact that participants in the 30 block condition had more practice trials as compared to the 10 block condition. The transfer phase might have appeared as a "surprise" to them as they were not given any indication that there was going to be a change in task. According to Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977), the more practice given to a component skill, the higher the chance that the skill will become automatic (Schneider & Shiffrin, 1977; Shiffrin & Schneider, 1977). Anderson's ACT theory further supported Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977) theory that becoming automatic with much practice reduces flexibility of composition as productions had become increasingly tied to the context of acquisition. This increases the

difficulty of activating these productions in new contexts. Therefore, the greater the length of training, the greater the slowing of performance on these skills when they are performed in a new situation resulting in greater disruption.

The disruption due to inflexibility that was noted in the 30 block condition during transfer could be further explained by the consistency of the task environment and amount of practice during training which has encouraged the use of an automatic *stimulus-response* association towards the transfer task. The participants in this condition would have anticipated more problems of this nature for efficient information processing (Carlson & Yaure, 1990; Wenger & Carlson, 1996). However, this anticipation might have been inappropriately applied to the distractor task. When participants were faced with the new task, their mental set would have been affected thus leading them to require a *stimulus-evaluation-response* strategy instead. This *stimulus-evaluation-response* strategy would now be utilised in the distractor task requirement in the transfer phase. Although performance on the test task only required a *stimulus-response* association, due to the breaking of the mental set, a *stimulus-evaluation-response* strategy might have been applied. Due to a shift of strategy, this might have accounted for the immediate disruption on the test task observed in the two conditions.

The reason for this disruption due to an extra step of mental calculation is further supported by Lassaline and Logan's (1993) study using a dot counting task. The design of the current study was adopted from that study. Lassaline and Logan (1993) posited that with repetition of a particular pattern and practice at determining numerosity, presentation of that pattern should act as a cue for retrieval of the correct number from memory. This was congruent to the *stimulus-response* association method. They also demonstrated that it was conceivable that as the complexity of visual display increases with numerosity, it may take longer to simply encode the visual display. This demonstration is similar to the *stimulus-*

evaluation-response strategy which was mentioned above. The transfer phase of the current study had increased the complexity of the visually display with numerosity by including new stimuli into the old stimulus. The number of new stimuli varied for different test task and the new stimuli was of a different colour from the old stimuli.

Therefore, the findings of this study was congruent to Speelman and Kirsner's (2001) study that a change in context in which a skill is presented is enough to induce a performance disruption resulting in a slowed response time. This demonstrated to be at odds with the implication of domain-general and domain-specific theories as the findings seem to indicate that more fundamental factors than simply the extent to which two tasks require the same knowledge may need to be considered to account for the nature of skill transfer.

Transfer disruption

An additional analysis was carried out to further investigate if there was a relationship between disruption and the amount of training in the block prior to transfer. The results of the analysis demonstrated that there was a positive relationship between training and amount of disruption. However, the nature of this relationship was at odds with the prediction. It has failed to support the hypothesis that with more practice leading to better performance, transfer disruption will be reduced. The final results of this study have revealed that with more practice, more disruption during the transfer phase was observed. This finding was noted in the 30 block condition and according to Anderson (1982), Schneider and Shiffrin (1977) and Shiffrin and Schneider (1977), this was due to the inflexibility of being able to transfer the much practiced "old" skills to a new context.

Research by Carson and Shin (1996) and Carlson and Yaure (1990) indicated that in comparison to trials containing a single rule presented in a consistent order, multiple processing rules are required when trials are performed in a random order (Carson & Shin, 1996; Carlson and Yaure, 1990). This study has found evidence that in the latter case, as it is

impossible to anticipate the requirements of the upcoming task, there is a need to alternate between the rules required to execute the task in working memory. Due to the need to alternate between the rules for coordination as the mental set have been broken, the problems would be solved at a slower rate as compared to problems that required only a single rule. Because of the alternation between the *stimulus-response* association and the *stimulus-evaluation-response* strategy, an increase in response time is observed in both the block 10 and 30 conditions during the transfer phase. An alternation within the working memory was required to accommodate the transition from a consistent task environment to one that included the random presentation of the test task and distractor task. The increase in response time is due to the fact that more resources are required to manage the allocation of the activity (Gopher, Armony, & Greenshpan, 2000). This proposition accounted for the disruption noted by Speelman and Kirsner (2001) that the introduction of a new task may have broken the mental set due to a conceptual context change, forcing a re-assessment of task requirements.

Given that additional processing was required to alternate the rules in working memory and to manage the requirements of an evaluation component, participants performance on the test task condition were expected to slow down. According to Carlson, Sullivian, and Schneider (1989), a contextual interference may be attributed to the cause of overlapping or similarity between an entire set of rules required to perform multiple tasks that was loaded into the working memory.

The findings of this disruption from training to transfer in both the conditions have contradicted both Anderson's and Logan's predictions regarding skill transfer. In both the training and transfer task, identical stimuli were utilised. Anderson posited that productions that were formed earlier during training would be employed, resulting in complete transfer. The outcome that was demonstrated by Anderson was predicted by Logan as well. Logan

theorised that since there were identical problems, the instances that were created earlier during training phase would be utilised in the transfer phase, resulting in complete transfer.

The results of this study regarding transfer demonstrated that mean reaction time for the first block of transfer was significantly slower than the last block of the training phase, indicating that full transfer had not occurred for extrapolation of the learning curve. Since transfer performance has often been predicted by extrapolating the improvements indicated by the learning curve and skill acquisition and transfer theories, the fact that performance increased rather than decreased in a novel situation can be interpreted as being indicative of a disruption. This occurrence has been an overall reflection of pattern of performance task when distractor tasks are present. However, these findings usually apply to the initial introduction of the distractor task and do not generalise across the entire transfer phase. Although the current findings clearly indicated performance on the test task was disrupted in the first block of transfer, there was an improvement in performance by the second block of transfer. This suggested that there was no existence of a prolonged disruption as participants may have overcome the effects of contextual interference with practice. This was in support with Speelman and Kirsner's findings that performance returned to normal after only a few blocks indicating only a temporary disruption.

Shiffrin and Schneider (1977) revealed that the effects of interference are overcome when controlled processing occurs. That is, greater allocation of attentional resources while processing. When the features of two stimuli are similar, greater allocations of attentional resources are required to distinguish between them. With more practice, controlled processing becomes more automatic, thus requiring fewer resources to attend to task requirements. This can be demonstrated in the 10 and 30 block conditions. Although there was transfer disruption in the first block of trials, there was a gradual decrease in amount of disruption in the second block of trials.

Transfer recovery

As prolonged disruption was not present in this experiment, we sought to examine transfer recovery. Transfer recovery was defined as skills performance improving with practice after being disrupted. As stimuli presented in the two blocks of transfer were identical, it may have enabled the participants to recover more quickly from the disruption induced by the substantially different distractor task. The performance associated with the test task problems in the transfer phase revealed that there was a differential rate of recovery between the initial disruption and as the transfer phase progressed. The findings of this study were a direct opposite of our prediction such that the block 10 condition made a quicker recovery than block 30 condition despite experiencing minimal practice trials during training. This can be interpreted such that, with less automaticity in the acquiring of skills in the block 10 condition, there was more flexibility in activating those productions in a new context. At the same time, with performance improvement after experiencing the first transfer block of trials, we can suggest that the power law of learning did occur from the first block of transfer to the second block of transfer.

Accuracy

Despite the observation that disruption did occur from training phase to transfer phase and later recovered, accuracy was noted in this study as well. The results of this experiment demonstrated that a change in task can affect the speed of which old skills are executed. An interesting finding to discuss here is that there was no effect on the accuracy of performance. Accuracy in the study maintained high in all conditions regardless of the phase. The gains made in the training phase were maintained throughout the transfer phase. This is also congruent to the findings of Speelman and Kirsner (2001), who revealed that performance accuracy was not affected by the introduction of novel tasks. In a study by Gagne and Foster (1949) on the acquisition and transfer of motor skill, results demonstrated that in a dimension

of similarity along which lie the stimuli included in the preliminary training, often fewer errors would result than in dimensions which the stimulus had not been used in training (Gagne & Foster, 1949). This suggests that any transfer disruption on well-established skills may be restricted to performance speed rather than performance accuracy.

The disruption in response times with the absence of the effect of accuracy have been demonstrated in Speelman and Kirsner's (2001) study, Giesen's (2000) study, as well as the current study. The three studies had employed skills based on arithmetic knowledge. Giesen's study was based on the multiplication table, Speelman and Kirsner's study was based on the calculation of a water analysis task, and the current study required basic counting.

Theoretical Implications

The assumptions and conclusions of many current theories of skill acquisition and transfer has been a challenge to the findings of the current study and those of Speelman and Kirsner (2001). The assumption made by Speelman and Kirsner (2001) regarding skill acquisition and transfer have suggested that the extent to which a skill can be transferred to another domain requires more than just a simple evaluation of previously acquired knowledge. It requires the context in which it will be performed in. The current study has clearly demonstrated that it is not appropriate to solely concentrate on the manner in which skills were acquired when determining their applicability to novel situations. As this is one of the main assumptions of current transfer theories, this study as well as Speelman and Kirsner's (2001) study have certain implications for the structure of those theories.

Transfer model theories

The methods and the type of tasks that were employed in the study were expected to demonstrate similar predictions from domain-general and domain-specific theories of skill acquisition. The execution of the test task in this study employed memory retrieval of fundamental skills instead of the application of algorithmic processing which was identical to

Lassaline and Logan's (1993) dot counting study. Therefore, direct comparisons between the two theories of skill acquisition were possible. Domain general theories such as Anderson's (1982) ACT theory have posited that the transfer of skills may be applied to situations that were not previously encountered as long as the there is some similarity in the productions that have been developed. Alternatively, domain-specific theories such as Logan's (1988) Instance theory of automaticity would predict that transfer would be a function of the degree of similarity between the specific stimuli presented in both tasks.

The design of this study had presented identical stimuli in both phases and according to the theories stated, there should have been a complete transfer. The results of this study have demonstrated otherwise being at odds with the predictions made by the theories based on domain-general and domain-specific accounts of transfer. However, it was noted that during the transfer phase, although skill performance was disrupted, it had not return to the level that was measured at the commencement of practice. This might be indicative that there was some degree of transfer between the two tasks despite the fact that it had not extrapolated the power of the learning curve. While it has been demonstrated that skills may be transferred from one domain to another, it appears that these skills are sensitive to the context which it is applied.

Limitations and future research

The limitation of this study was that the data in the 20 block condition was lost due to a computing error. With that lack of data, we were unable to determine whether a certain type of training might provide an advantage when performing a new task. Future research should include this 20 block condition to investigate if this block of data might be able to predict the hypothesis that transfer disruption may be predicted by prior training performance.

Based on the current results, it was demonstrated that when there was a slight alteration in the presentation of stimulus, there was much disruption in skills. This indicated

the fragility of skills. For future research, more practice should be included in a block to equip an individual with sufficient skills to reduce disruption in a novel situation. As more tasks are introduced to a block now, distributed practice should be recommended. Although Speelman and Kirsner (2001) had demonstrated that skills function as encapsulated wholes and improve according to the particular learning function (e.g., whole-task training), Adams (1987) indicated that there is an advantage of distributed practice over massed practice as an effect of performance.

Speelman and Kirsner's (2001) study, Giesen (2000) study, as well as the current study has demonstrated that introducing a novel stimulus to a situation could result in disruption and have used arithmetic skills as a basis to investigate transfer disruption. Arithmetic skills is only one selection of the wide range of other abilities which humans are capable of. It would be beneficial for future research to examine whether other fundamental areas such as planning and problem solving would demonstrate a performance improvement or disruption.

As the current study did not provide any feedbacks while training was in progress, future research may include feedbacks. Singley and Anderson (1989) have suggested that as long as immediate feedback is given on incorrect productions, it will be quickly eliminated during transfer. The negative transfer from these incorrect productions will be limited to the first few trials of the transfer tasks.

Conclusion

While the study has failed to support the hypothesis that transfer performance may be predicted on the basis of training performance, it has demonstrated that the disruption noted by Speelman and Kirsner (2001) is a legitimate aspect of skill acquisition and transfer. The results of the study provided an indication that the power learning curve extrapolations may not be relied upon as a valid description of predicted transfer performance. A disruption of

performance was demonstrated with the slightest contextual change. This was highly at odds with the current theories of skill acquisition and transfer that have based their explanations on the predictions derived from the power law. The results of this study in the transfer phase have failed to support both Anderson's ACT theory and Logan's Instance theory. The theories had posited that with identical stimuli present in both conditions, positive transfer should have occurred. Although there were identical stimuli present in both conditions in this study, transfer performance was disrupted. This indicated that even though a person may possess the knowledge required to perform the skill and positive transfer should have taken place, without the appropriate cues being present in that context, application of the skill is restricted.

In conclusion, firstly, transfer performance cannot be predicted on the basis of training performance as predicted by the two theories of skill acquisition and transfer. Secondly, skills acquired in one context have demonstrated to be fragile in another context. That is, any slight change in the presentation of the context will result in disruption of performance.

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Appendix A

Stimuli used in Training Phase

6 Stars
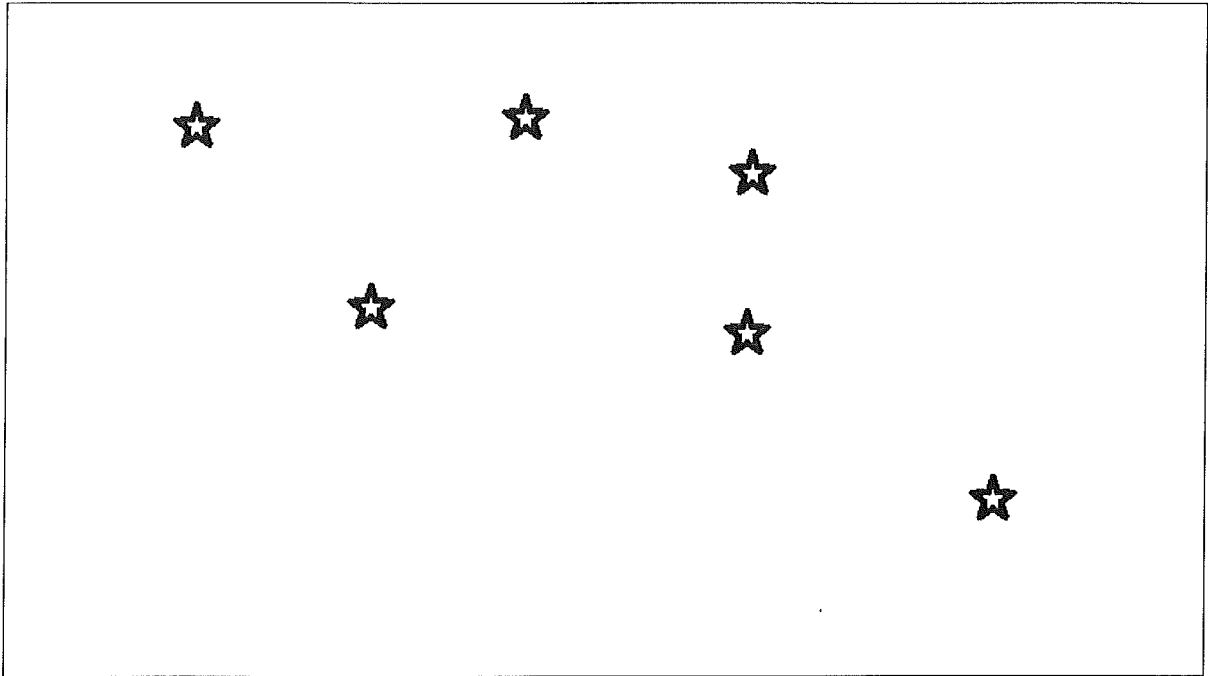
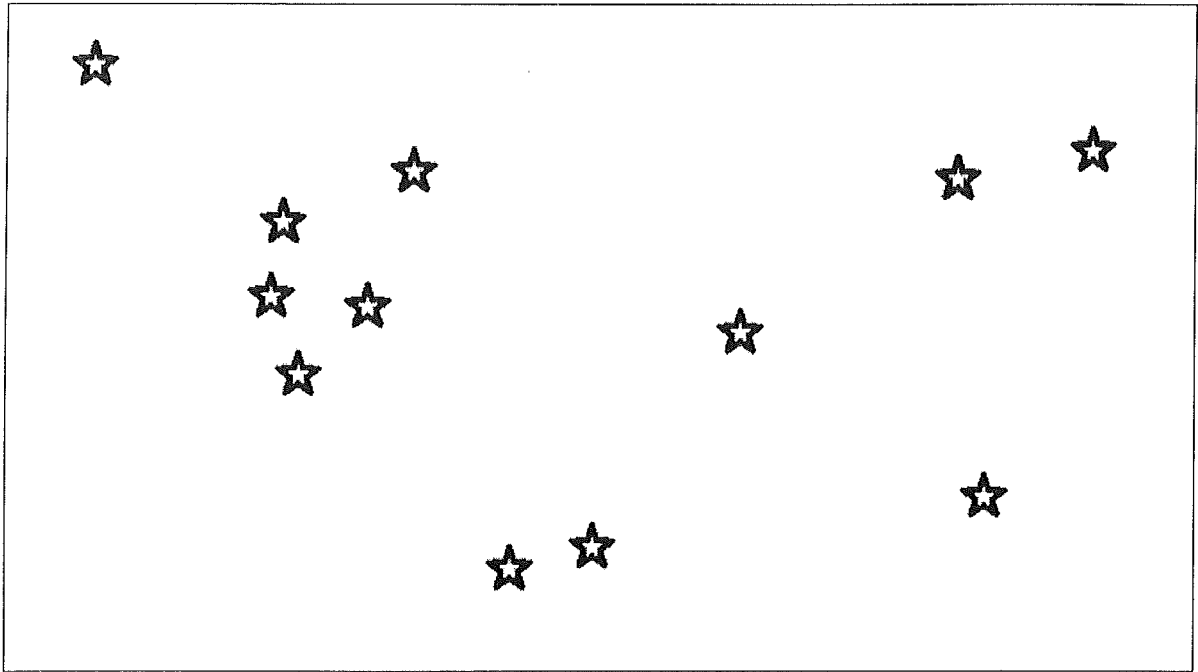Appendix A

7 Stars
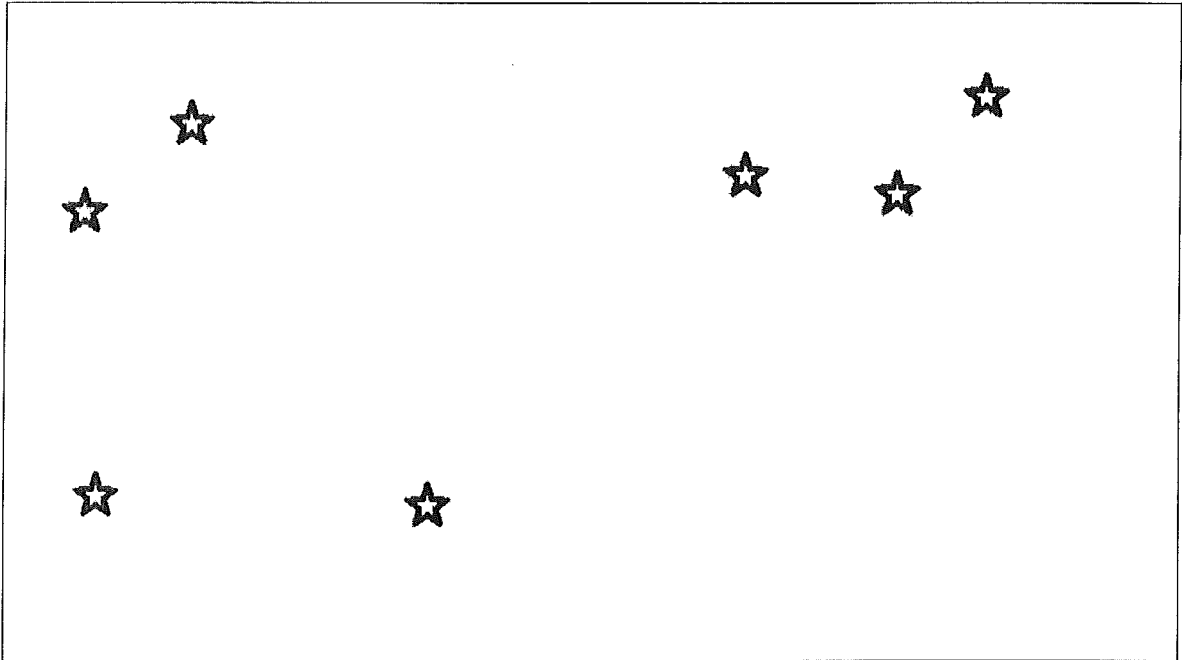
Appendix A
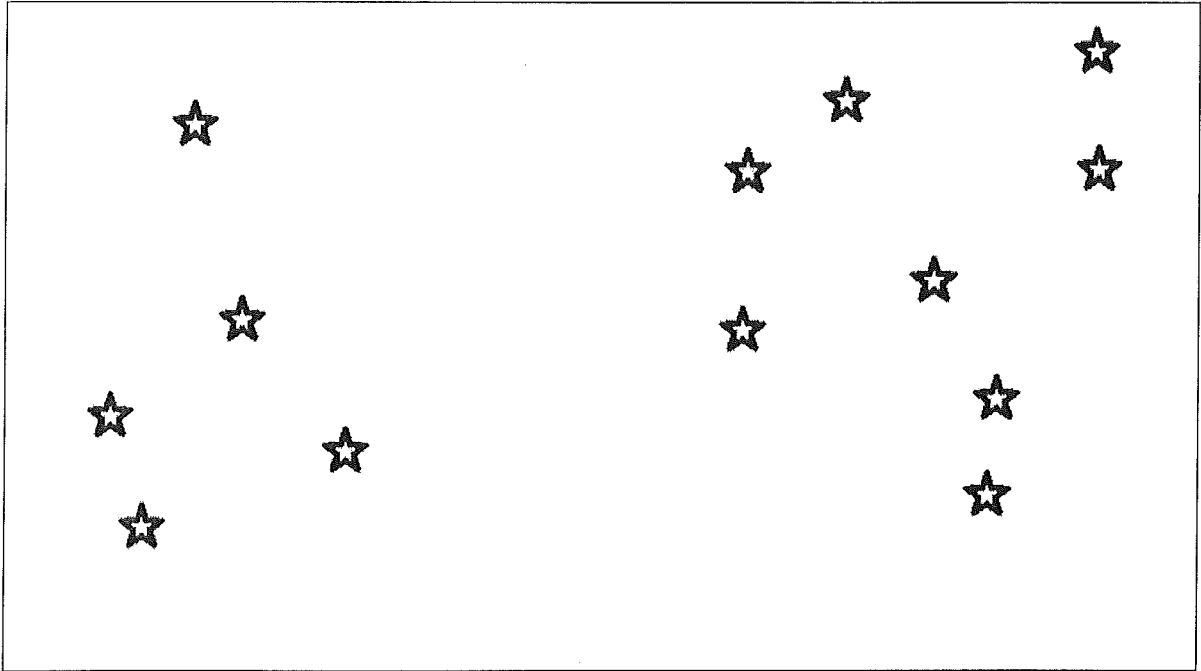
8 Stars
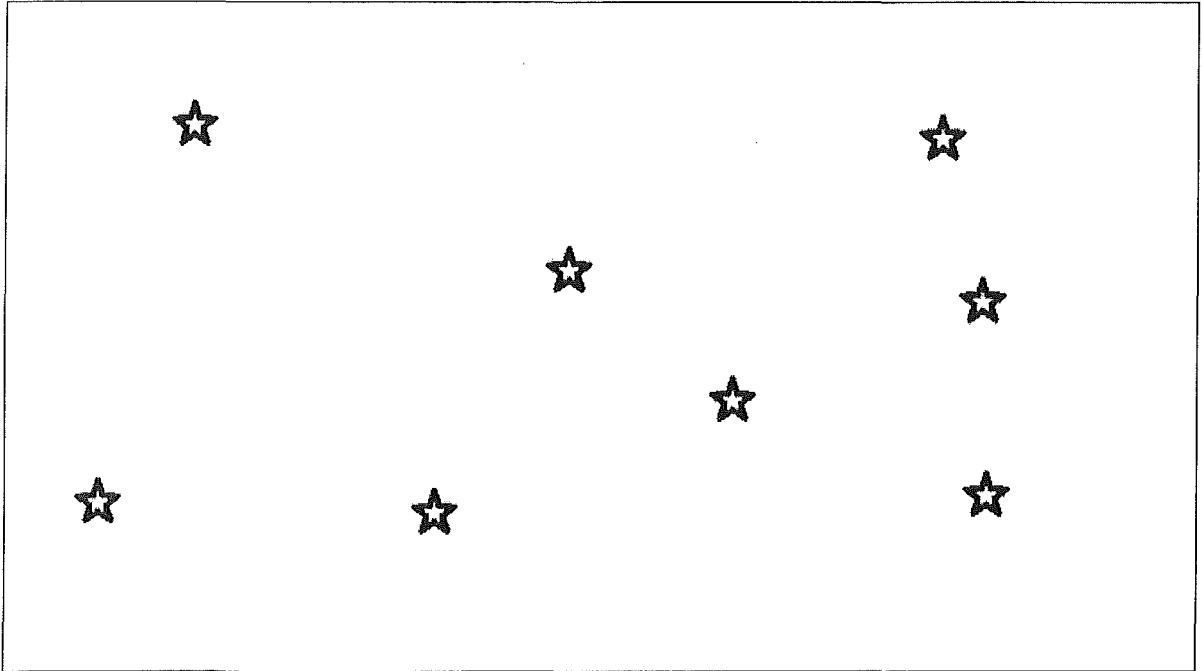
Appendix A

9 Stars
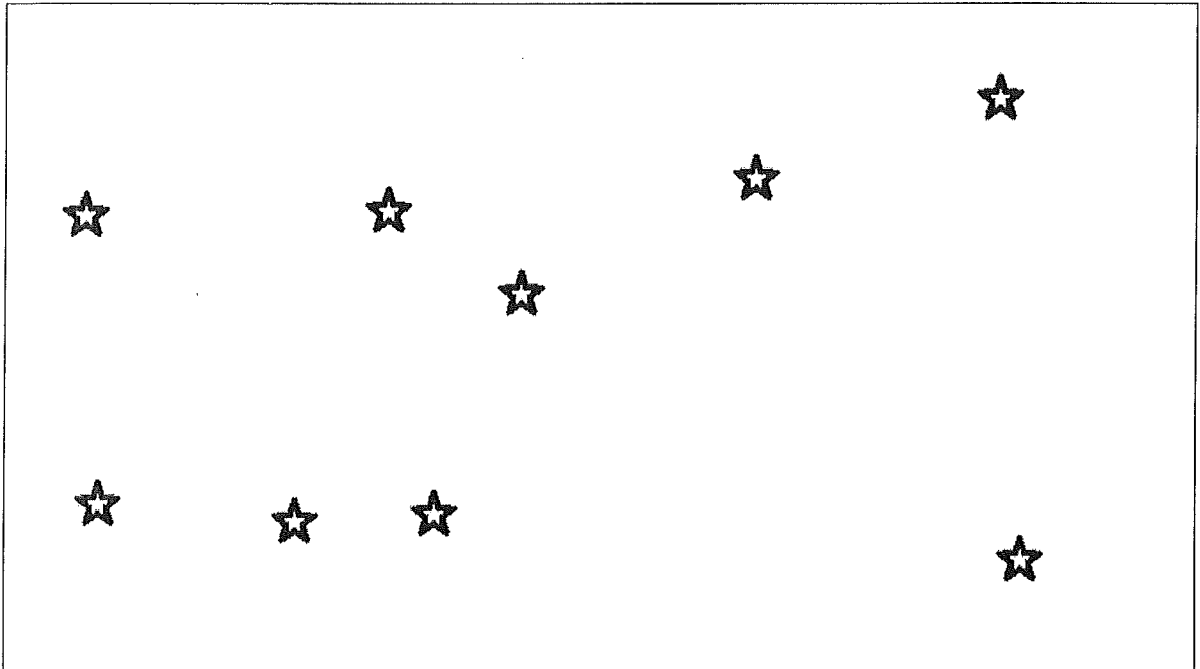
Appendix A

10 Stars
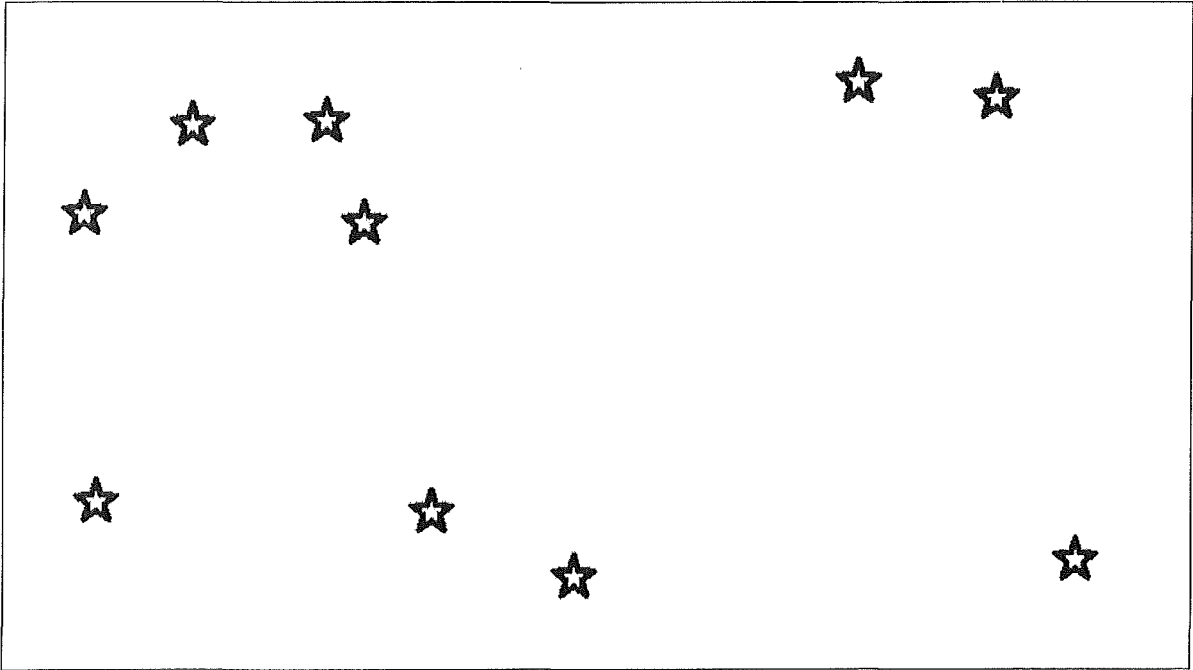
Appendix A

11 Stars
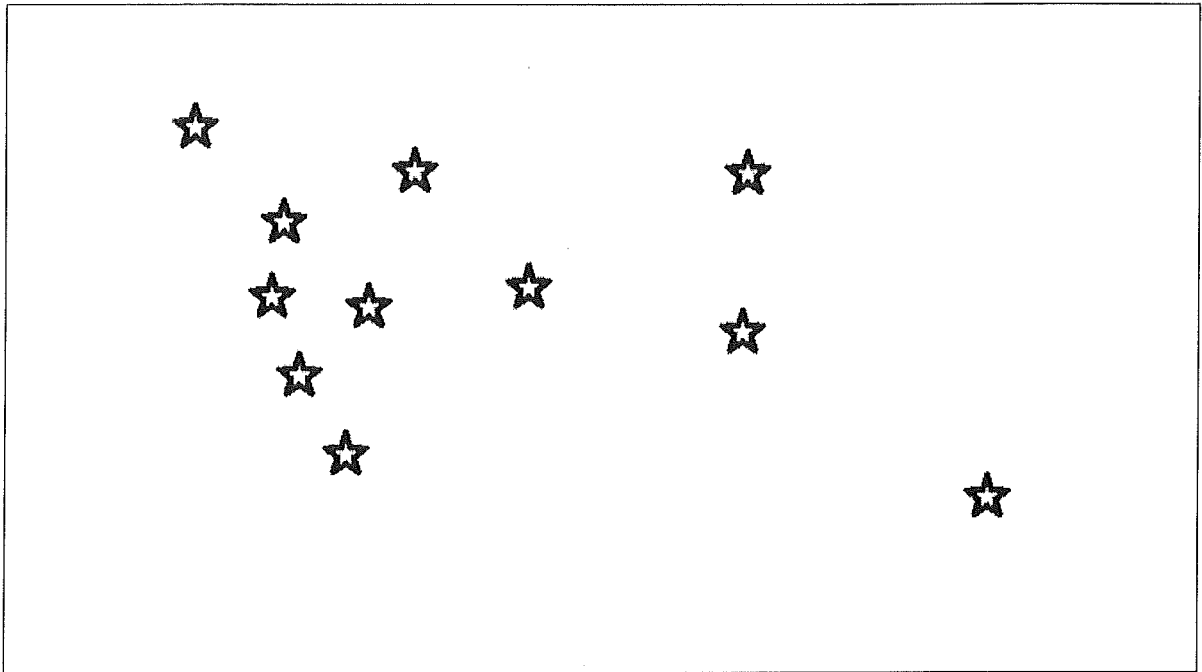
Appendix A

12 Stars
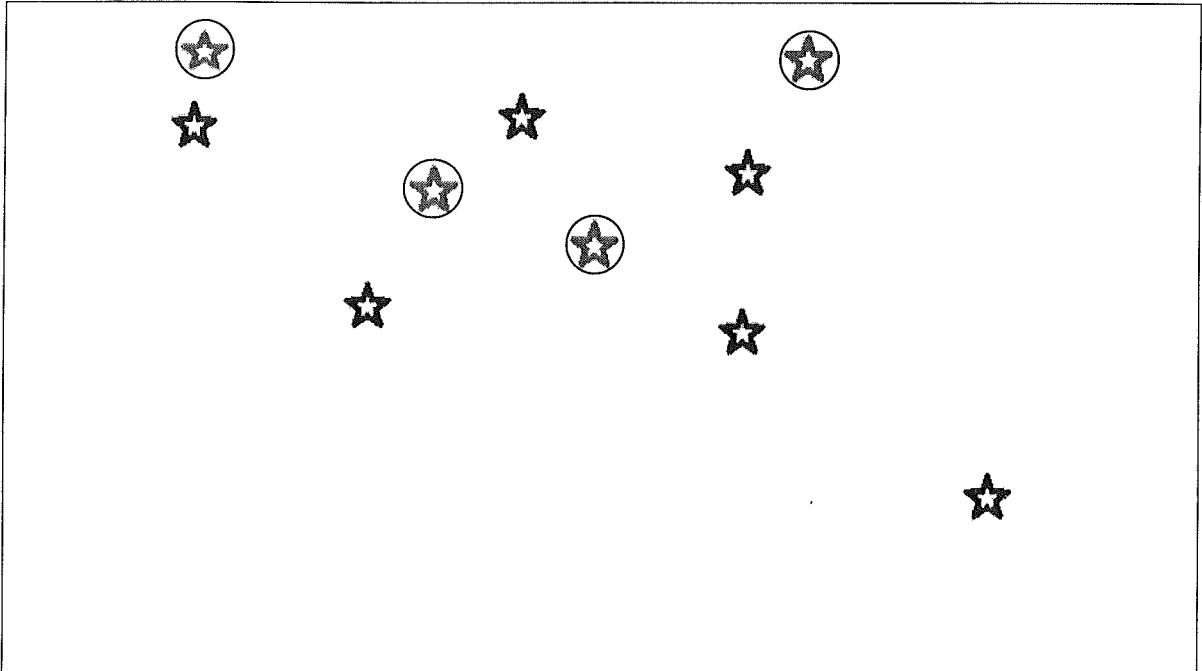
Appendix A

13 Stars

Appendix B

Stimuli used in Transfer Phase
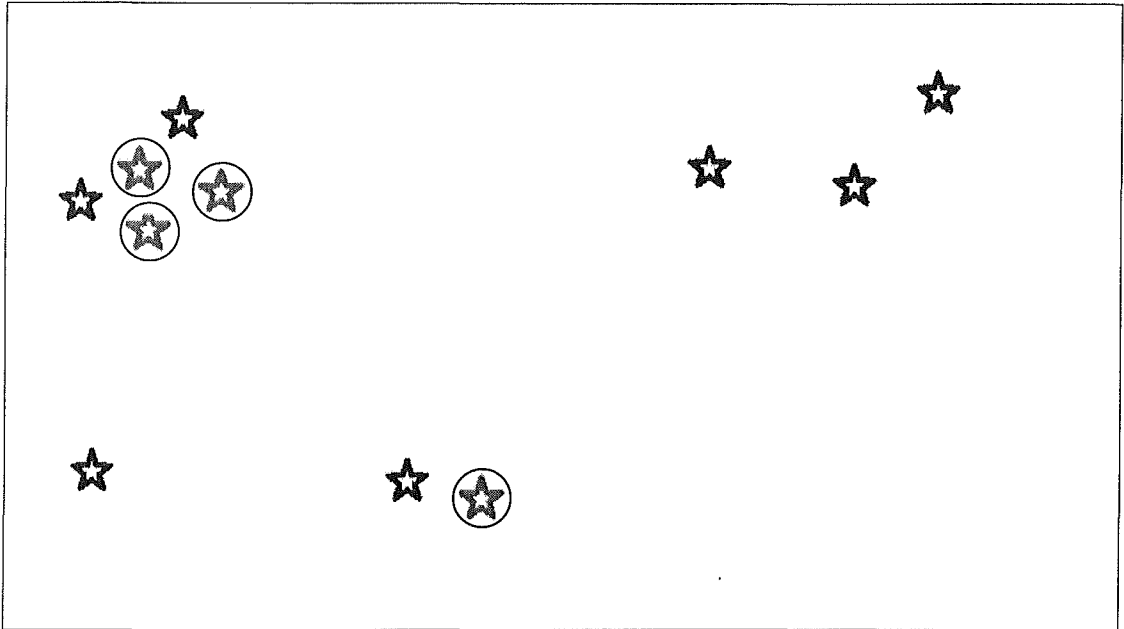
Circles denote red stars
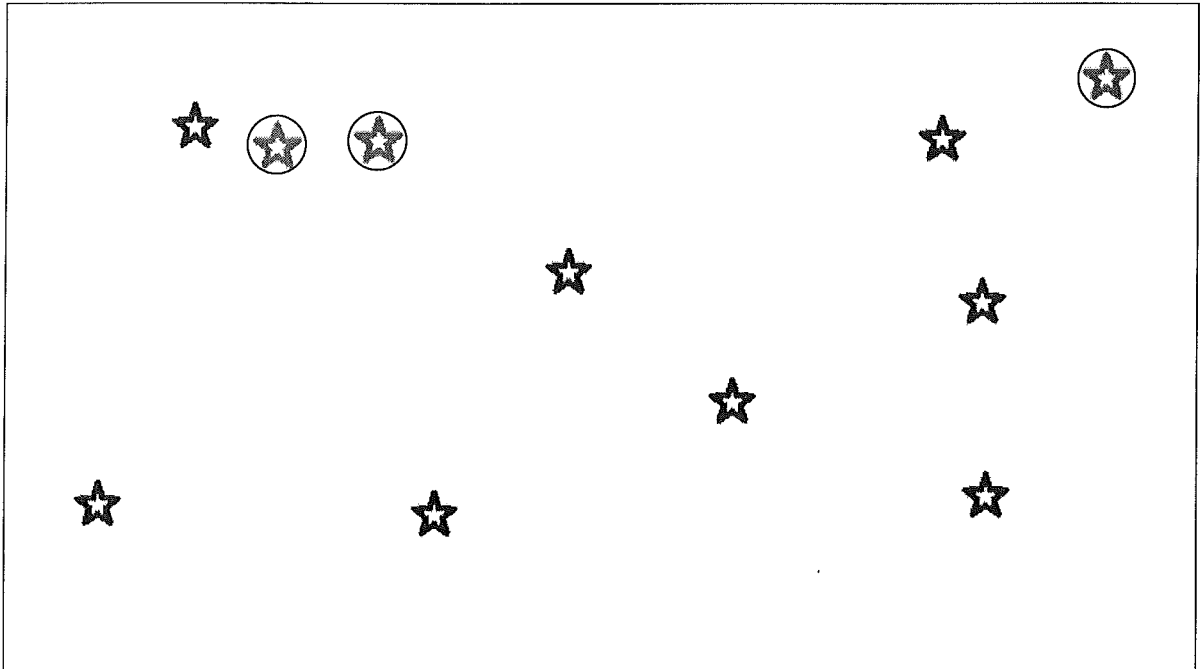
6 + 4 Stars

Appendix B

Circles denote red stars
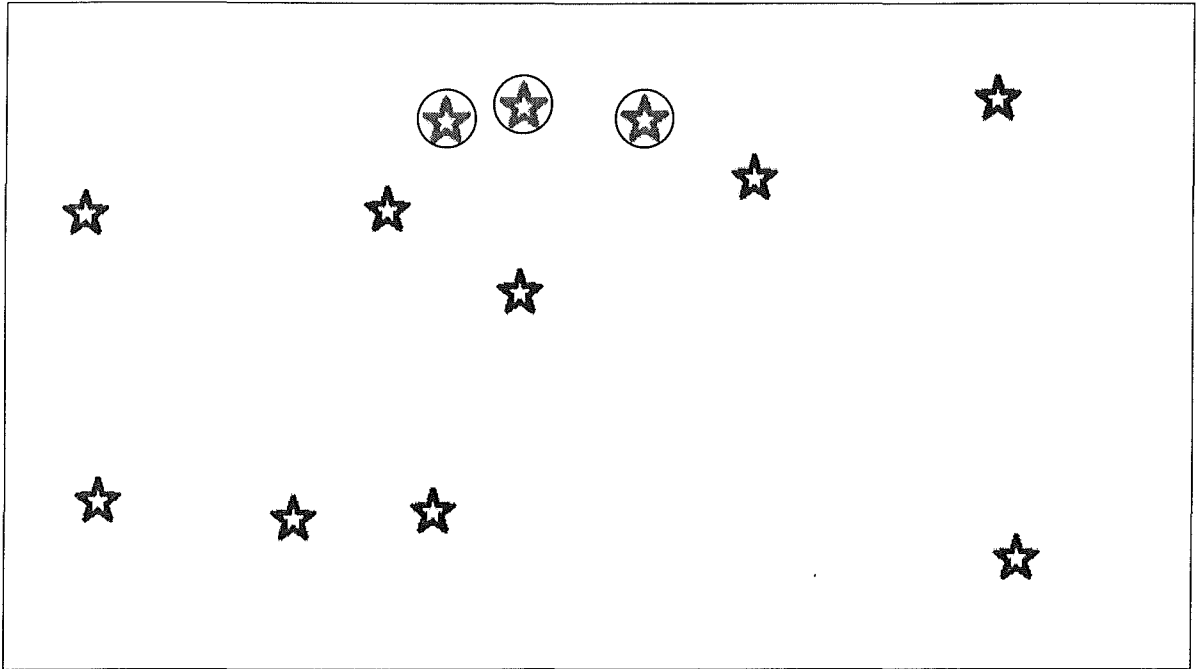
7+4 Stars

Appendix B

Circles denote red stars
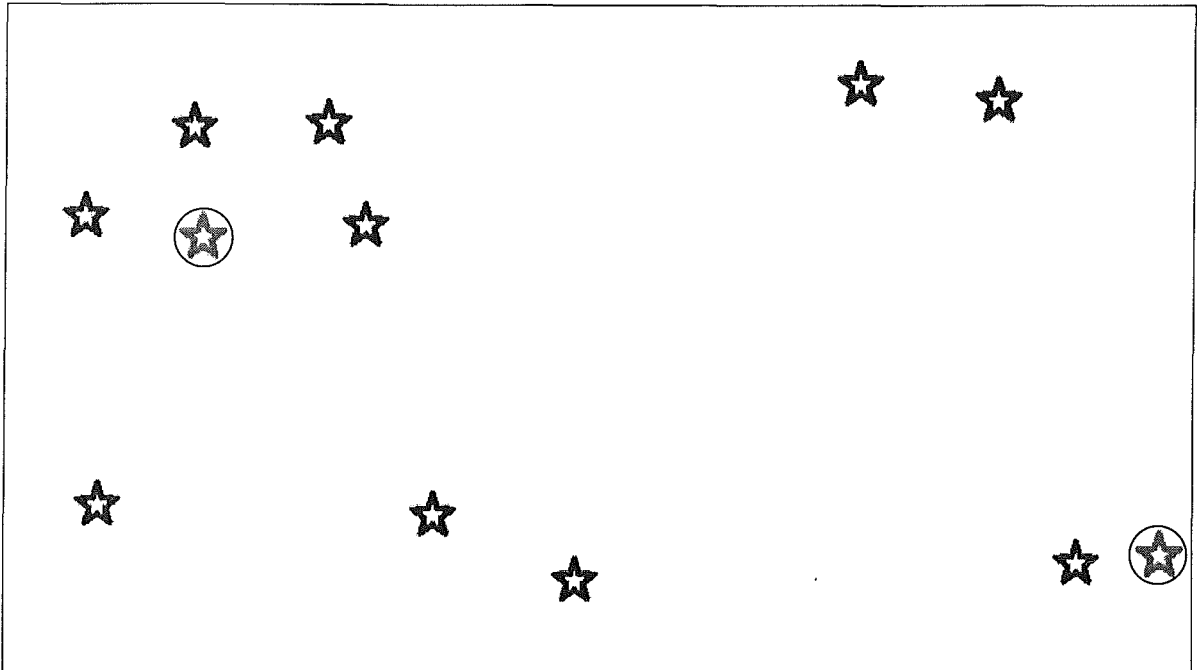
8+3 Stars

Appendix B

Circles denote red stars

9+3 Stars

Appendix B

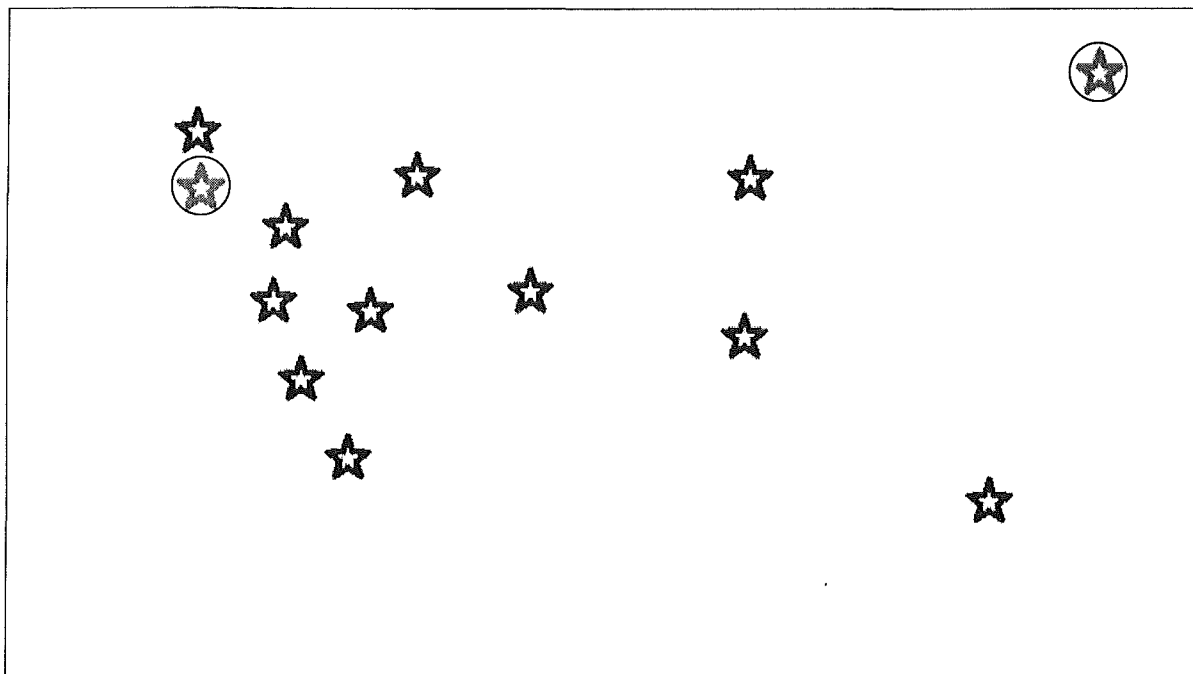## *Circles denote red stars*

10+2 Stars

Appendix B
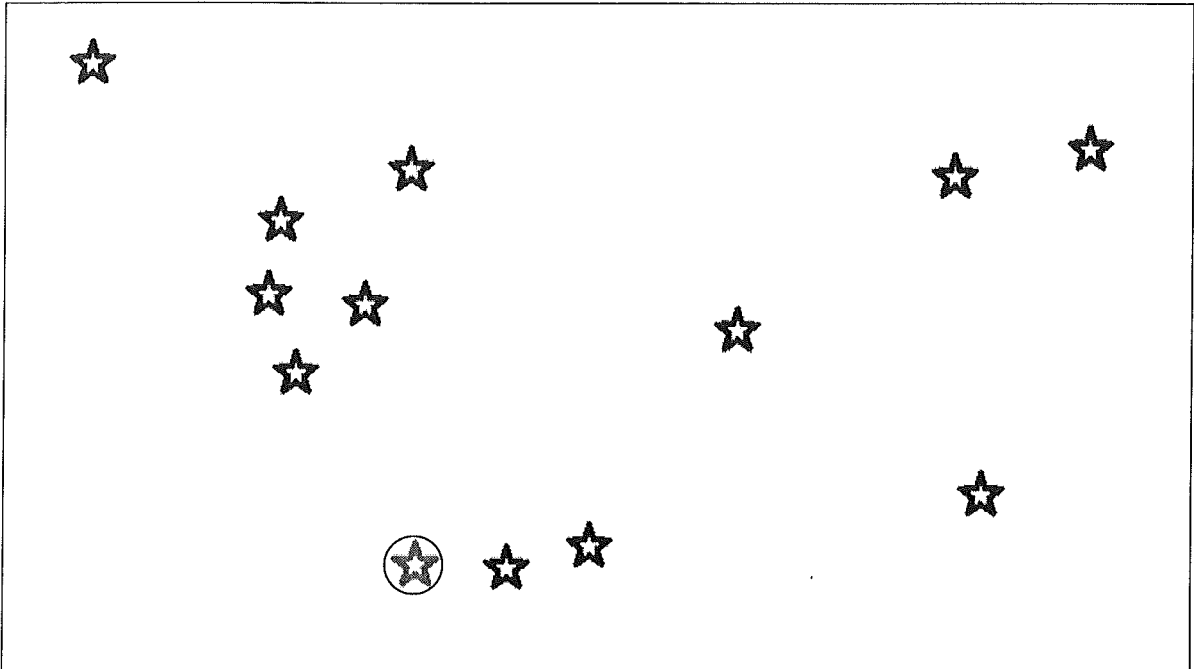
Circles denote red stars

11+2 Stars

Appendix B

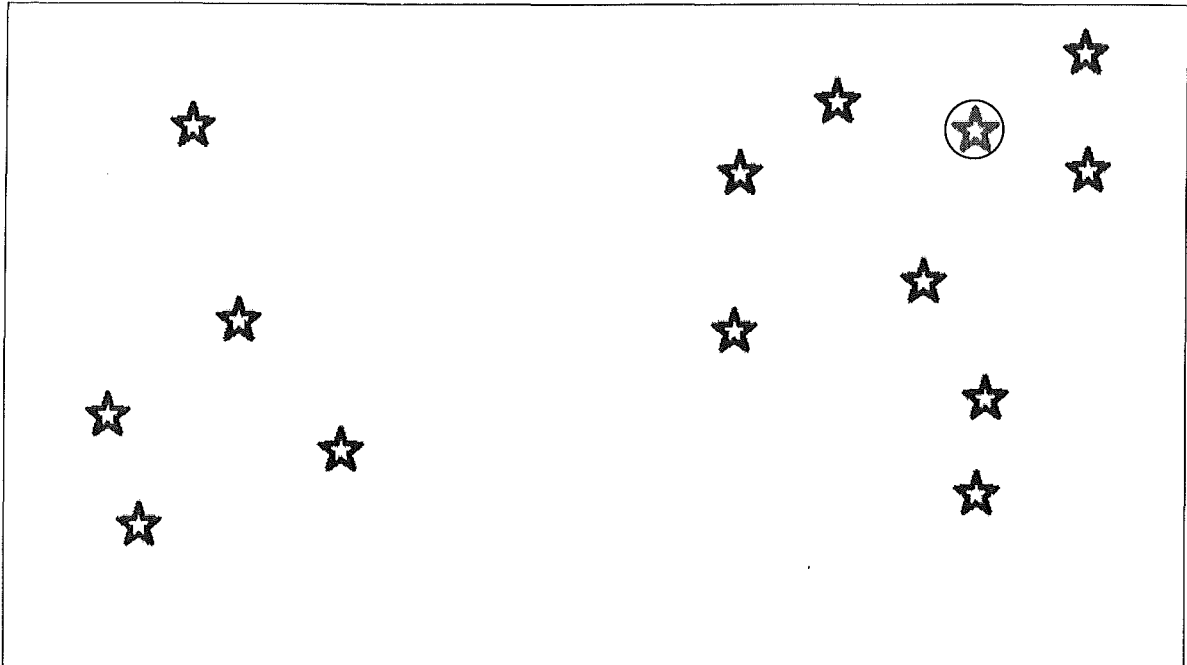*Circles denote red stars*

12+1 Stars

Appendix B

Circles denote red stars

13+1 Stars

Appendix C

Information Letter

My name is Jacinta Avril Tan and I am currently completing my Honours in Psychology at Edith Cowan University, Joondalup Campus. This project is being undertaken as part of the requirement for my Psychology Honours Degree. I appreciate your interest in being part of this study and your input is valuable.

The purpose of this study is to examine how practice improves performance on simple cognitive tasks. It is anticipated that the task that you are required to complete will take approximately 1 hour. It will be carried out in the memory and cognition laboratory inside the ECU School of Psychology and Social Science. You will be required to complete a dot counting task. The dot counting task requires you to count the number of dots and respond if there is an even or odd number of dots. The time take to complete the task and the accuracy of it will be recorded.

Any information collected during the study will remain strictly confidential with any identifying information being omitted from my final research presentation. Information collected from the study may be used in future research. Your identity will not be disclosed at any time. It will be protected and not be published in any reports. Once the task is completed, the information collected will be downloaded into a thumbdrive and will be stored securely at the University site.

Your involvement in this study is voluntary and you are able to withdraw at any time. No explanation and justification is necessary. If you withdraw from the research, you also have the right to withdraw any information that has already been collected.

If you do have interest about the outcome of the research project, I will be pleased to share it with you upon its completion which is scheduled on 29 October 2010. My contact number will be listed below.

If you are interested in participating in this research, it is required of you to complete the informed consent document before participating in the study. This study has been approved by the ethics committee.

If you do have any questions about the research or any further information about the project, do not hesitate to contact me (details attached), or my supervisor, Professor Craig Speelman (6304 5724). However, if you do wish to speak to someone who is independent of this research project, please contact the fourth year coordinator, Dr Justine Dandy (6304 5105).

Thank you for taking the time to consider being part of this research. It is greatly appreciated.

Contact details:
Jacinta Avril Tan
Mobile: █████████
Email: stan19@our.ecu.edu.au

Appendix C
Participant consent form

I, _____ have read the information sheet

provided and agree to participate in the research conducted by Jacinta Avril Tan of Edith

Cowan University. I have read the information letter and have understood the purpose and

nature of the study. My participation is voluntarily. Any queries I had have been answered to

my satisfaction and I grant the permission for the information collected to be used in the

process of completing a Honours Psychology degree and acknowledge that it may be

published. I understand that my name and any other personal information which may identify

me will not be used. I understand that the information collected from this experiment will be

used in future research. I understand that I can withdraw from the research at any time

without any explanation or justification.

_____   _____

Research Participant   Date

_____   _____

Primary Researcher   Date

Appendix C

Instruction Sheet

Thank you for your interest in and giving your time to participate in this research.

For this experiment you will be required to complete a simple counting task. A series of display screens will be shown to you with a number of stars on them. Your task is to count the stars on the screen and indicate whether there are an 'ODD' or 'EVEN' number of items by pressing the allocated buttons on the response pad.

To begin the task a "READY" screen will be displayed. Please press the TOP LEFT hand button on the response pad when you are ready to begin. The first display screen will appear immediately after your response.

If you determine the number of stars in the display to be an 'ODD' number, please indicate by pressing the BOTTOM LEFT button on the response pad marked "ODD".
If you determine the number of stars in the display to be an 'EVEN' number, please indicate by pressing the BOTTOM RIGHT button on the response pad marked "EVEN".
At some point during the experiment, there will be a slight change in the display. However, your task remains unchanged. That is to say you must count ALL items in the display and respond 'ODD' or 'EVEN' accordingly.