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The role of awareness of repetition during the development of automaticity

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The Role of Awareness of Repetition during the Development of Automaticity.

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A report submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Arts (Psychology) Honours

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I declare that this written assignment is my own work and does not include: (i) material from published sources used without proper acknowledgement; or (ii) material copied from the work of other students.

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The Role of Awareness of Repetition during the Development of Automaticity.

Abstract

Investigation into the influence of contextual information on performance of an automatic task has found inconsistent results. The majority of studies have investigated whether changing the context of a simple cognitive task can inhibit an automatic response, but do not review whether context can help the development of automatic responding. The current study examined whether bringing awareness to the context of a simple numerosity task could aid the development of automaticity. It also examined whether participants were aware of when automaticity developed for them via a post-test interview. The numerosity task used in this study was a simple counting task requiring a numerosity response to stimuli presented on a computer screen, like that used in Lassaline and Logan (1993). Thirty-four participants were divided into an experimental group (n=17) and a control group (n=17), and completed 30 blocks of 18 trials on the simple counting and numerosity task. The experimental group was provided with the information that the stimuli repeat many times over practice in the written instructions before beginning the task. The results showed no significant differences in the way automatic processing developed between groups. Similarly participants were not aware of when the transition from controlled to automatic processing developed. These results have theoretical and practical implications for instance theory and learning of basic mathematical skills.

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The Role of Awareness of Repetition during the Development of Automaticity

It is commonly observed that repeatedly practicing a task can lead to a change in performance over time from slow and deliberate to fast and seemingly without thought (Logan, 1988; Wilkins & Rawson, 2011). Everyday life is full of examples in which information is automatically used to complete repetitive tasks without using much mental power to do so; a phenomenon known as automaticity (Epstein & Lovitts, 1985). In Psychology, there are two kinds of cognitive processing; controlled processing, where performance is deliberate, limited by memory capacity and requires attention, and automatic processing (Schneider & Shiffrin, 1977). Automatic processing occurs without a person's control, without capacity limits, without necessarily demanding attention and develops over time with much practice of a task (Epstein & Lovitts, 1985; Logan, 1988, 1990). With practice, a person can transition from controlled to automatic processing. These distinct types of processing and their respective characteristics have been supported through observation of many search and attention tasks (Shiffrin & Schneider, 1984). Evidence for the transition from controlled to automatic processing after practice has been provided in many simple cognitive tasks including alphabet-arithmetic, lexical decision, Stroop paradigms, relative judgement, categorisation and dual-task scenarios (Augustinova, Flaudias, & Ferrand, 2010; Hélie, Waldschmidt, & Ashby, 2010; Hommel & Eglau, 2002; Loft, Humphreys, & Neal, 2004; Logan, 1990; Logan & Klapp, 1991). Although this transition and the distinction between processing types is clearly evident in these tasks, one clear theoretical stance on how it occurs has not yet been agreed upon.

Theoretical Background

Schneider and Shiffrin (1977) reviewed and summarised research in detection, search and attention studies relating to automaticity. They concluded that controlled processing is a temporary activation of a new mental sequence allowing performance of a specific task that is not yet learned. Due to being a new task, the mental sequence required to respond is relatively easy to modify and use in new situations. This controlled processing also requires short-term memory capacity and attention in order for a correct response to be made. Alternatively automatic sequences are well established and do not require attention as the connection between a stimulus and response has been consistently mapped many times. This allows a response to occur regardless of the memory load required as the whole sequence is automatically activated when the stimulus is presented. In turn automatic processing is not constrained by short-term memory capacity limits. This two-process theory prompted a great deal of research into automaticity.

Logan (1988) demonstrated that a memory-based account provides a credible explanation of the phenomenon of automaticity. Automaticity has been defined by memory-based theories as having no attentional requirements, making it seemingly effortless, fast and unavailable to conscious influence (Logan, 1991). As aforementioned, the development of automaticity has been shown in many simple tasks; all of which tend to be consistent in nature, requiring a stimulus to be mapped directly and consistently to a response over a period of practice (Strayer & Kramer, 1990). Given this environmental consistency, memory for responses can be utilised automatically rather than generating a response in a controlled manner for each stimulus. That is, rather than generating a response by working through several processing steps, a stimulus can automatically activate a memory for the required answer.

Instance Theory

Logan (1991) reported results of several experiments that provide significant support for his instance theory account of automaticity. Instance theory suggests the transition from controlled to automatic processing reflects a race between the application of an algorithm to produce a response and a memory process that retrieves a response based on past experiences (Logan, 1988; Wilkins & Rawson, 2011). For example, when solving 4x6=? we might move from generating the answer through an addition strategy (i.e., 6+6+6+6) to directly remembering an answer (i.e., 24). The state of automaticity is said to have been attained when retrieval of an answer is faster than the controlled calculation of an answer. The theory states that during repeated performance of a task, mental representations of the task, the response and the outcome accumulate and are stored in memory. These mental representations are referred to as instances. These instances are also retrieved during performance. Initially this retrieval is slower than the generation of an answer (Choplin & Logan, 2005; Logan, 1988, 1990). As experience grows, more instances accumulate in memory. This increases the chance that retrieval of an instance can occur faster than the generation of an answer, and an automatic response (i.e., retrieving and responding on the basis of an instance) becomes more likely (Logan, 1991).

When most people learn a new task, performance improves in a general pattern known as the learning curve (Haider & Frensch, 2002). This learning curve takes the form of a power function with larger performance improvements at the beginning which slow over time with more practice. The learning curve function follows the equation of $\boldsymbol{RT = a+bN^{-c}}$, where *RT* is reaction time for the task, *N* is the number of practice trials and *a, b* and *c* are constants. *a* represents an asymptote which is the minimum limit on performance that is approached but not necessarily obtained (Haider & Frensch, 2002; Klapp, Boches, Trabert, & Logan, 1991; Logan, 1992). Logan (1988, 1990) has demonstrated that this pattern of performance improvement in the shape of the learning curve can be accounted for by the accumulation of instances in memory over practice. An example of a power function learning curve is presented in *Figure 1*.

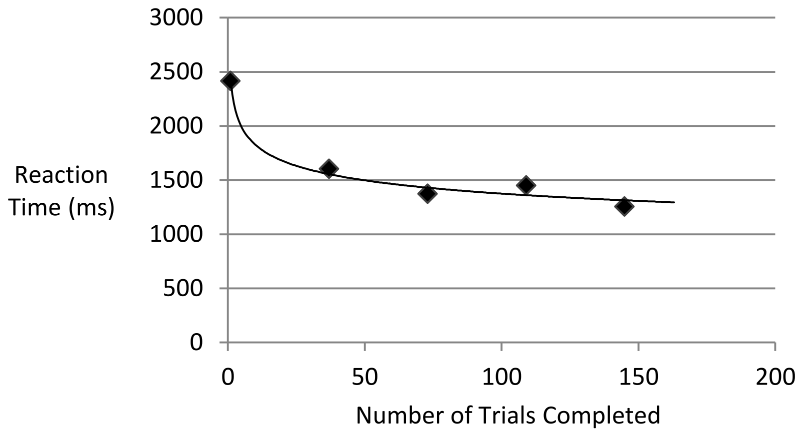

Figure 1. Example of power function of learning.

Attention and Instance Theory

The role of attention in the development of automaticity is also discussed within the discourse of memory based accounts such as instance theory. The quality of instances in memory seems to depend on attention given to the association between the stimulus and response during practice (Boronat & Logan, 1997; Logan, 1988; Schneider & Shiffrin, 1977). An attentional filter determines characteristics that are noticed based upon their importance for completing the task. The more important a characteristic is for completing a task, the more likely it will be attended to, and preserved in memory as instances (Lassaline & Logan, 1993; Moors & De Houwer, 2006). Automaticity is highly task specific, developing in consistent task environments whereby the nature of the task does not change over practice (Palmeri, 1997). Similarly instances are highly task specific representations in memory of the way in which the stimuli and responses are associated. Attention is important in the early stages of practice to learn the specific way in which a task needs to be performed (Palmeri, 1997; Yamaguchi & Proctor, 2011). According to instance theory, attention is required while developing automatic processing of the task but after automaticity is reached, it is no longer needed. Attention is not required later in practice because automatic processing occurs unconsciously allowing responses to become significantly faster (Logan, 1988; Strayer & Kramer, 1990).

Instances in memory have been shown to form during performances, as well as prior to performance when mental representations about how to respond are created by directing attention to the characteristics of the task (Cohen-Kdoshay & Meiran, 2007; Yamaguchi & Proctor, 2011). Mental representations develop into instances when instructions are given before the task about how to correctly respond to the stimuli that will be presented. These instances formed on the basis of intention allow the person to respond more rapidly than if specific instructions were not given. Although no practice has taken place, instances can be formed by directing attention to the association between a stimuli and a responses before any performance takes place (Cohen-Kdoshay & Meiran, 2007). Given this, it follows that by deliberately directing attention to the nature of the association between the stimulus and responses before the development of automaticity, the rate at which automatic processing develops may be quickened; although this has not yet been extensively explored within the cognitive psychology literature.

Alternative Theory

In contrast to the memory-based models of automaticity, process-based models suggest that automaticity develops as a result of better execution of cognitive processing involved in responding correctly. According to these theories, improvements in performance result from improvement in process execution rather than the transition from algorithmic calculation to memory use (Anderson, 1982; Jonides, Naveh-Benjamin, & Palmer, 1985). These models do not see the progression from controlled to automatic processing as a race between two separate processes, rather the quickening and improvement of the same one (Anderson, 1982). It would then follow that because there is one processing type, improvements in performance as a result of practice in one task could be transferred to a second very similar task without lapsing back to slow, deliberate performance. Although these theories have merit, this is inconsistent with findings that automaticity occurs only in highly task specific contexts and that transfer is very limited, with significant lapses in performance even in very similar tasks (Moors & De Houwer, 2006). Process and memory based theories both have merit in explaining automaticity, but given that instance theory is more consistent with Logan's findings, and the current study is based on this work, instance theory is the focus of this paper (Lassaline & Logan, 1993).

The Stability of Automaticity

Automaticity, according to the memory-based models, has traditionally been seen as a stable and predictable phenomenon in many simple cognitive tasks (Logan, 1988; Strayer & Kramer, 1990). Although this is still supported in the literature to some extent, there is debate as to whether the development of automaticity is as stable as previously thought. This debate encompasses whether context and directing attention during a task can impact the development of automatic processing. It also investigates whether people have a level of conscious control over processing that was previously not acknowledged for this type of processing (Epstein & Lovitts, 1985; Wilkins & Rawson, 2011).

Influencing Development Speed

Although the existence of automatic processing has been largely supported in previous research there are few clear findings with regard to the influence of the level of awareness of, or attention given to contextual characteristics of a task (Boronat & Logan, 1997; Epstein & Lovitts, 1985). It is evident that characteristics of the stimuli attended to during the formation of instances such as spatial extent, item identity and pattern are important in the memory retrieval process (Green, 1997; Kramer, Di Bono, & Zorzi, 2011). However what is unclear in the literature is whether deliberately directing attention to such characteristics of the stimuli before performance can impact the rate at which automaticity is reached. The importance of these characteristics and their preservation in the instance representations are determined by the nature of the task and an attentional filter as mentioned above (Lassaline & Logan, 1993).

Additionally, what is yet to be determined is whether being aware of contextual factors is important for developing automaticity. Contextual factors are surrounding facts that determine the nature of a task not specific to the individual task characteristics, such as the repetitious nature of a task (Epstein & Lovitts, 1985). If being aware of these factors could allow responses based on memory to occur faster, the development of automaticity would occur quicker.

Semantic Stroop Evidence. Following this idea, Dishon-Berkovits and Algom (2000) used a semantic version of the Stroop task to demonstrate that a change in contextual information can impact automaticity. The Stroop task involves naming the ink colour of colour words; when ink colour and the word meaning are unmatched it hinders our ability to name the colour of the ink (e.g., with the stimulus word "**RED**" written in black ink, the correct response would be black, but the automatic response is red). This Stroop effect suggests that processing the meaning of words is automatic, resulting from frequent reading practice in everyday life. Dishon-Berkovits and Algom (2000) manipulated the probability of matched or unmatched trials across many trials, changing the context of the task. If the Stroop effect was a true result of automatic processing then automatic responses would occur to each unmatched stimulus, regardless of the surrounding context. However the results demonstrated that the exhibition of automaticity was affected by a change in context, questioning the nature of attention in true automaticity. When the proportion of matched/unmatched trials was patterned in a way that was easily recognisable, for example when 97% of the trials were matched, the Stroop effect (resulting in incorrect answers) was evident in all unmatched trials. However when the probability of having a matched/unmatched trial was equal, and the occurrence of these trials was in a random order, the Stroop effect disappeared with practice. In unmatched trials participants learned to ignored the meaning of the word allowing correct responses regardless of matched or unmatched stimulus. As the context had been made irrelevant to the task due to being unpredictable, the Stroop effect disappeared. This suggests that automaticity may be affected by contextual information and thus a less stable phenomenon than previously thought. It also highlights that selectively attending to contextual information seems to be important when completing a task where context is relevant for performance.

Augustinova et al. (2010) contradicted the suggestion that the semantic Stroop effect is sensitive to manipulations intended to direct attention to context, like that in Dishon-Berkovits and Algom (2000) study. The 2010 study indicated that the Stroop paradigm is still automatic and not possible to influence given colouring and spatially cuing single letters in the task. No difference in the exhibition of the Stroop effect was found across multiple manipulations of context. This raises the question as to whether directing attention to contextual information can change the speed and development of automaticity itself.

Labuschagne and Besner (2015) more recently utilised a semantic version of the Stroop task to attempt to provide clarity to this debate. Their experimental results suggested that lexical-semantic processing (processing the meaning of a word), which is believed to be automatic, can be eliminated by creating a change in spatial attention and therefore context of the task like that in Dishon-Berkovits and Algom (2000). Again this study emphasised support for the suggestion that automaticity may not be stable across varied contextual conditions, and attention to contextual information may impact its development.

Numerosity Evidence. Similar to the Stroop task, there has been research conducted on the automatic processing of number symbols (Pansky & Algom, 2002). Number symbol tasks can include tasks such as numerical magnitude and numerosity judgements. Numerical magnitude refers to the symbolic value of a numeral or the meaning of the numeral when read, whereas numerosity refers to the quantity of objects presented. For example if there is a digit presented on a screen as “8”, the numerical magnitude is eight, whereas the numerosity is one. Due to high exposure to numbers and their meaning in everyday life, numerical magnitude information is believed to be automatically retrieved in number symbol tasks. Pansky and Algom (2002) showed in tasks of this nature automatic attention directed to numerical magnitude can be supressed when the task required only a numerosity judgment. For example when the digit ”8” was presented on the screen, participants were able to respond with the numerosity “one” without attending to the numerical magnitude (meaning of the number) “eight”. This supports the idea that automatic activation of numerical magnitude information may be influenced by how relevant the information is given the context of the task at hand (Dormal & Pesenti, 2013). Given that the task did not require attention to the meaning of the digits being presented, this information was appropriately ignored, preventing automatic processing from occurring.

Similarly Naparstek and Henik (2010) also used number symbols to look at automatic processing of numerosity in a comparative judgement task (bigger or smaller than 5) and a parity task (judgment of odd or even). These two tasks provide different contexts for a number symbol task. The automatic activation of numerosity should occur in both tasks if there is no attention given to the context. Contrary to this, automatic activation of numerosity occurred in the comparative judgement task but not in the parity task. This supports the idea that automatic activation is influenced by contextual information and that automatic processing is not stable across contexts. It appears that rather than automatically processing numerosity in both tasks, the response was only elicited when the context of the task rendered numerosity important. Given that the comparative judgement task required attention to be given to the numerical meaning of the digits, processing of numerosity was automatically activated. Alternatively the parity task did not require attention to be given to numerical meaning, and thus numerosity was not automatically activated.

Overall there is a growing body of evidence that indicates that context can influence the exhibition of automatic responding. The evidence suggests that by changing the context of a task, the automatic activation of a response can be prevented. Automatic processing of information appears to be dependent on context, which in turn raises the question if context can also improve the speed of developing automaticity, rather than just preventing an automatic response. Although there seems to be continuing debate surrounding this topic, there is a need for clarifying evidence and potentially a revision of our understanding of how automaticity develops.

Control of Cognitive Processing

Another relevant aspect of automatic processing is the level of control people have over memory retrieval during skill acquisition (Nosofsky, Clark, & Shin, 1989; Wilkins & Rawson, 2011). When performing a repetitious task, responses stored as instances in memory are retrieved during both controlled and automatic processing. As a result changes to long term memory can be observed. Fisk and Schneider (1984) demonstrated that there are observable changes to information stored in long term memory after performance of a task requiring controlled processing, but very little change after performance of automatic tasks. These changes to stored information were observed by participants recognising distractor words (background information not relevant to the task) that were used in a simple judgement task. Automatic processing was shown when participants did not attend to background information such as distractor words during the task, therefore no changes to long term memory occurred. This lack of change to long term memory is due to already having sound pre-established connections between a chain of nodes in memory required to perform the task. When one node is activated, even weakly, by the stimulus presentation the whole chain is activated resulting in an accurate response with little change to long term memory storage. They did however show that during an automatic task if a person deliberately allocated attention to controlling their performance by intentionally attending to both the judgement stimuli and distractor words while calculating a response, the information was stored in long term memory as if controlled processing were taking place. This deliberate control over processing type and resultant change to the information stored in long term memory shows that people have the ability to influence the way in which a task is cognitively performed.

Similarly, Wilkins and Rawson (2011) reported that control of memory retrieval processing is possible in an alphabet arithmetic task. Alphabet arithmetic tasks involve responding true or false to a problem presented. The problems involve having a starting letter from which you add or subtract consecutive letters in the alphabet according to the number in the equation (for example A + 2 = C is true, whereas A + 5 = C is false). These problems were presented a number of times over the test in order for them to become familiar and allow automatic processing to develop. It was found that when instructions for speed rather than accuracy were provided, the use of memory retrieval for responding was encouraged. In contrast when instructions for accuracy rather than speed were given, participants remained reliant on using controlled processing, generating answers by manually adding or subtracting letters in every trial. The group instructed for speed showed that by using memory retrieval to respond, faster performance and faster development of automaticity was enabled. This further supports the significance of deliberately attending to task related information like context prior to or during practice when developing automatic processing. This finding also suggests possible control over the way in which a task is cognitively processed, however it does not definitively show whether deliberately attending to contextual information is important in allowing faster development of automaticity. This possible influence of contextual factors requires further investigation.

Lassaline and Logan's Study

One clear example of the development of automaticity is the simple counting task used by Lassaline and Logan (1993). Four participants were presented with images of dots, ranging in number from six to eleven on a computer screen. Six to eleven dots were used to eliminate smaller patterns being 'subitized' which could mask the observable learning effect due to practice (Green, 1997). Subitizing results from easier recognition of smaller numbers of items, in turn resulting in more rapid and accurate responding for numbers below six which would mask any variability in counting reaction times (Jensen, Reese, & Reese, 1950). The task involved counting and responding to the number of dots as quickly and accurately as possible. The dot patterns were repeated for four blocks of 120 trials. Each participant completed 13 sessions of the four blocks, totalling 5760 trials. Patterns were presented in a random order within blocks. This allowed people to respond quicker with each performance as they came to rely on their memory for each pattern of dots rather than having to count them.

Lassaline and Logan's (1993) counting task provides a clear example of algorithm use early in practice. At this point the counting of dots is a controlled process requiring attention. Later in practice when memory is relied upon to recognise a dot pattern, automatic processing is used. The task showed the clear distinction between when the task was controlled or automatic. The results showed that with practice, reaction time moved from being directly related to the number of dots presented, to being equal for all numbers of dots presented. This relationship between reaction time and the number of dots was shown to follow a significant linear trend as depicted in *Figure 2.*

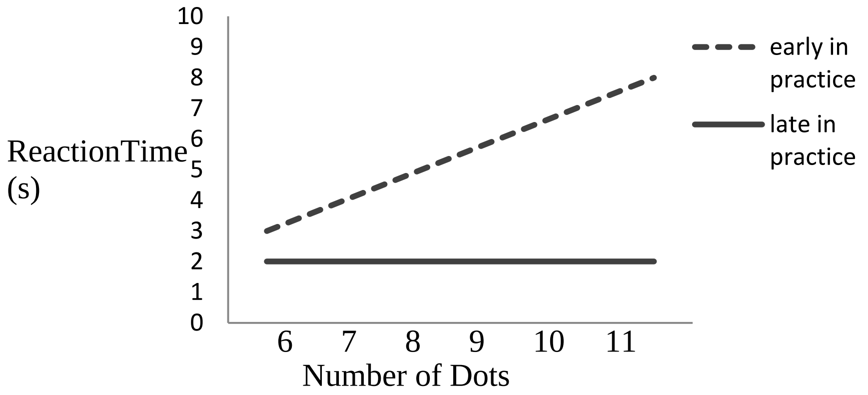

Figure 2. Example of reaction time before and after developing automaticity.

Due to this significant linear trend, the slope value in the function relating reaction time and numerosity was used to observe the change from controlled to automatic processing as learning took place. As practice went on, the slope values of the reaction time and numerosity function reduced reflecting participant’s movement from relying on controlled processing by counting, to memory retrieval of instances by automatically recognising patterns for each number of dots. In Lassaline and Logan’s experiments, the slope in the first session was significantly greater than that for all other sessions, with the slope values reaching asymptote by session four reflecting when automaticity was reached. This counting task provides clear evidence of how and when automaticity is reached, providing a sound example of the process and measurement of developing automaticity. The current study was based on this numerosity task.

Automaticity and Basic Mathematics

Understanding the nature of automatic processing and how contextual factors may influence it within an educational context is important as factors that impact the process of automaticity could in turn impact the effectiveness of learning (Estudillo, Estefania Bermudo, Casado, & Jay Prasad, 2015; Jackson & Coney, 2007). This area of research has implications for the development of better teaching methods for young children learning basic numerosity skills in mathematics as automatic processing is essential (Baroody & Ginsburg, 1990; Estudillo et al., 2015). It has been well established that automatic retrieval of answers from memory is frequently used as a cognitive mechanism during performance of simple addition, multiplication, and subtraction tasks (Estudillo et al., 2015; Ganor-Stern, Tzelgov, & Ellenbogen, 2007; Orrantia, Rodríguez, & Vicente, 2009). Performance of simple arithmetic skills resulting from automaticity can have a significant impact on any person's life as they are used in many everyday settings (e.g., shopping or scoring in sports, Estudillo et al., 2015).

Preschool children already possess informal mathematical skills such as counting, which are built upon in order to improve formal learning during school. Such formal learning may include manipulating numbers via addition, subtraction, division and multiplication. Formal learning relies on children being able to assimilate new information with what they already know. This is in contrast to the directive 'rote' learning style of teaching that is commonly adopted within the education system (Baroody & Ginsburg, 1990). By encouraging the development of automaticity by directing attention to the contextual or patterned information surrounding simple arithmetic tasks, automaticity may develop and improve performance at a more effective rate. This may in turn form a stronger basis from which to further build mathematical skills.

Automaticity development for arithmetic skills is important as it has been shown to account for some of the difference between low and high skill levels for simple arithmetic in adults (Jackson & Coney, 2007). There has been a concerning decline in the numerosity ability of the general population, with only 53.5% of adults in Australia reaching capabilities to answer relatively simple questions in common contexts such as percentages and measurements (ABS, 2013). Improvements in mathematical ability has also been shown to be positively linked to future job success for students (Hemmings, Grootenboer, & Kay, 2011). Given this, any advancement in knowledge that would effectively improve teaching these skills is considered highly valuable.

The evidence discussed above suggests clear benefit may be gained by further research into testing the effects of providing contextual information before performance. For example providing knowledge of the repetition within a task may prompt faster development of recognition of patterns and instances upon which a person can then rely. This in turn may allow faster, more effective development of automaticity in simple arithmetic tasks.

Purpose of Present Study

To date there is conflicting evidence relating to the stability of the development of automaticity across differing contexts and situations. This suggests further investigation into the influences on automaticity may be beneficial. The purpose of this study was to test the influence of providing contextual information on the rate of automaticity development. A similar dot counting task based on Lassaline and Logan's (1993) study was used as it provided a sound example of how automaticity develops in a simple numerosity task. The task allowed the manipulation of awareness of the repetition of dot patterns before the task via pre-experimental instructions. The first aim of the present study was to test whether bringing awareness to the repetition of patterns could encourage memory retrieval and increase the speed at which automatic processing developed. It was expected that if such awareness quickened the development of automaticity there would be an interaction effect for learning between the experimental (aware) and control groups. This interaction would occur such that in the early stages of learning (such as block 1 or 2 of 30) the aware group would have an advantage with faster reductions in reaction time. After the third or fourth block when automaticity should have developed for most participants, reaction times for both groups should become stable near the asymptote level of automatic responding. Once this occurred there would be no significant differences in the later blocks of the experiment. These predicted patterns in reaction time are depicted in *Figure 3.*

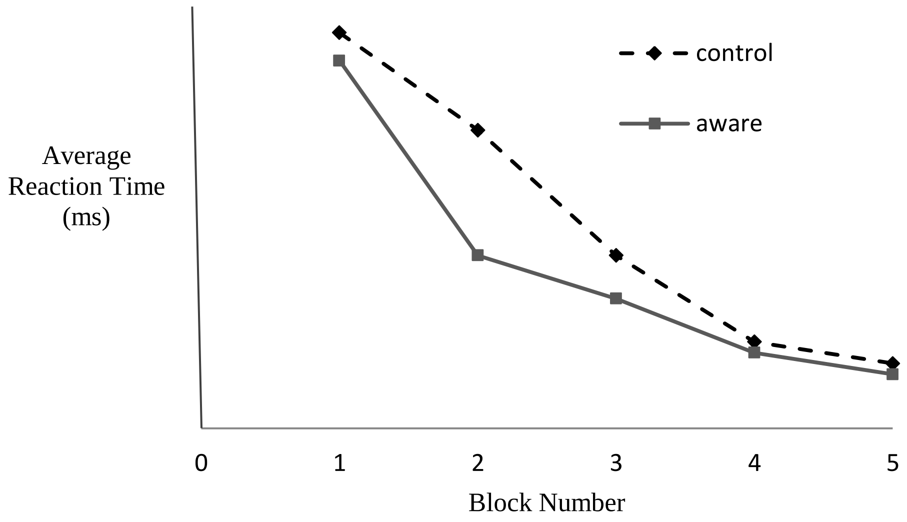

Figure 3. Expected pattern of results with the effect of group on reaction time.

The second aim of this study was to assess whether participants in the experimental (aware) group thought that being instructed to pay attention to the repetition of the pictures helped them perform the task. The participants' knowledge of when automaticity developed for them was reviewed via post experimental verbal questioning. This enabled the assessment of whether the time at which participants reported reaching automaticity was correlated to when the data suggested that they had attained it. This also established if the experimental group was more aware of the process of developing automaticity than the control group as a result of pre-experimental awareness of repetition.

Method

Design

This research project was conducted as a between subjects design following the experimental design of Lassaline and Logan (1993), with one experimental group and one control group. The independent variable was prior awareness of the repetition of dot patterns, which was manipulated through the administration of written instructions prior to commencing the task. The dependent variable was the reaction time of each participant, which allowed the speed at which automaticity occurred between the control group (not aware of repetition) and the experimental group (informed about the repetition) to be compared. This study also utilised a post-test interview conducted with each participant. The interview consisted of three questions relating to the participants' awareness of when automaticity developed over the period of practice and a debrief discussion of the results and project. This project received ethics approval from the Edith Cowan University Human Research Ethics Committee prior to commencement.

Participants

A total of 34 participants were initially tested, with one participant's results excluded from analysis as a result of low accuracy. Once this was discovered a 35th participant was recruited and tested in order to maintain equal sample sizes for the two groups. The two groups consisted of 17 participants each. The participants ranged in age from 18 to 62 years. There were a total of 17 men and 17 women. The final sample size of 34 participants was considered adequate, as this sample size exceeds the four participants used in Lassaline and Logan's (1993) study which clearly demonstrated automaticity and yielded clear, statistically significant effects. Each participant was an acquaintance of the researcher and was approached in person and supplied with an information letter. They were then asked if they would be happy to voluntarily participate in the research project.

Participants were asked verbally to confirm they had basic numerosity skills (could count to 15) and could clearly see a computer screen. These were the only two criteria for inclusion in the study. The information letter (Appendix A) included a detailed description of what was asked of the participants in the experiment, as well as clearly stating that their data would be kept anonymously within the School's archives after participation. It was also emphasised by the researcher verbally that participation was voluntary and that participants did not have to participate if they did not wish to and could stop at any point in order to avoid any coercion. Participants were assigned to an experimental or control group based on their availability. Participants were allocated in time order alternating between the control and experimental groups to maintain equal numbers per group. This also allowed any potential researcher biases to be avoided as it was purely based on when the participants were available to participate.

Materials

SuperLab version 5 (2014) software was used to prepare the programs for presenting the dot counting task. The task was presented on Dell PCs in the Memory and Cognition Laboratory of the ECU School of Psychology and Social Science. Pictures of dots were presented on the computer monitor and a SuperLab RBx30 series response pad attached to the computer collected key responses, accuracy and reaction time per trial. Buttons on the response box were organised in two rows, the first with six keys labelled 6, 7, 8, 9, 10 and 11 corresponding to the number of dots that were presented in the experimental stimuli, and the second row with two "NEXT" keys. The software presented one picture per number of dots for six to eleven dots. The set of pictures were repeated three times in a random order to form one experimental block (18 trials).

The stimuli consisted of four practice dot pictures and six experimental pictures. The four practice stimuli were in a clear symmetrical, domino-like formation. These stimuli were designed to be easily recognised patterns for the participants to count for the numbers 6 to 9. Conversely the experimental dot pictures were designed to look random in order to present patterns that are not commonly encountered in everyday life. The pictures were designed this way in order to allow performance gain due to learning to be easily observed and avoid the recognition of regularly encountered patterns in everyday life that could have been previously learned. The use of novel stimuli encourages algorithmic (controlled) processing while learning a new task (Wilkins & Rawson, 2011). An example of an experimental stimulus can be seen in *Figure 4*.

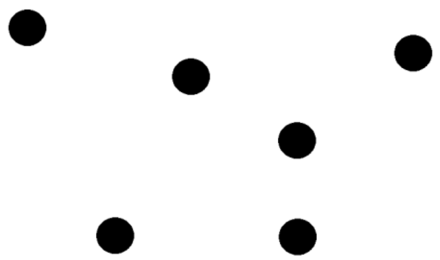

Figure 4. Experimental stimulus used for dot pattern with a numerosity of six.

The picture pattern used for each numerosity was unique; at least two dots differed in location on the screen to the picture of each other numerosity. The practice and the experimental stimuli pictures contained dots 1.5 cm in diameter. Images of each picture are presented in Appendix D. Six to eleven dots were used to eliminate smaller patterns being ‘subitized’ which could have masked the observable learning effect over practice (Green, 1997).

Procedure

Participants were approached by the researcher and asked to participate, reading the information letter and signing a consent form if they were willing to participate (Appendix A and B). The experiment was conducted in individual sessions in the laboratory, at a time convenient for each participant.

Instructions for each group were presented on the computer screen. These instructions outlined the nature of the counting task, and informed the experimental group only that the dot patterns would repeat, specifically drawing their attention to this characteristic of the design (Appendix C). Following the instructions each participant completed the 4 practice trials to familiarise them with the response keys before starting the experimental trials.

A fixation point in the middle of the screen appeared for 500ms before each trial. The dot picture was then shown and remained visible until the participant responded. After a response was made a feedback message (Correct/Incorrect) appeared on the screen for 2 seconds or until a “NEXT” key was pressed followed by the next fixation point. Each stimulus picture was repeated three times in each experimental block of trials in a random order making each experimental block 18 trials long. Participants completed 30 experimental blocks with optional breaks in between.

After the completion of the task a short post-test interview was conducted. First, the post-trial questions were asked verbally in order to explore whether the participants recognised the repetition of patterns and when automaticity developed (Appendix C). Participants were then debriefed about the conditions of the experiment, the expected results and applications of the study and thanked for their contribution. Each session took approximately 40 to 50 minutes to complete including the computer task, verbal questions and debrief.

Results

Accuracy Scores

Mean accuracy scores for the 34 participants across all experimental blocks ranged from 89.81% to 99.62%. Minimum accuracy per experimental block was also calculated and ranged between 55.56% and 94.44%. Any participant with an average accuracy score per experimental block below 70% was excluded from the data as low accuracy suggests guessing. This resulted in the exclusion of one subject who was replaced with a supplementary participant.

Comparison of Groups (Reaction Time)

The 30 experimental blocks of 18 trials each were combined to form 5 analysis blocks of 90 trials each. This was done in order to reduce variability within the data which otherwise would have made clear patterns hard to detect. Mean reaction times were calculated for each of the 5 analysis blocks per person.

Mixed Design Analysis of Variance – Reaction Time. A mixed analysis of variance (ANOVA) was conducted in order to examine the mean reaction time scores for the within-subject effect of practice, and the between-subject effect of awareness of repetition. As the assumption of sphericity was violated, the Greenhouse-Geisser adjustment was used. This ANOVA showed there was a significant reduction of reaction time over the 5 blocks, $F(1.94, 62.15) = 130.68$, $p = .00$ but no significant difference between groups, $F(1,32) = 2.72$, $p = .109$. There was no significant interaction effect for groups over practice either, $F(1.942, 62.15) = .27$, $p = .758$. Pairwise comparisons showed significant reductions in reaction time over all five blocks (M = 2644.28ms, M = 2196.21ms, M = 1961.31ms, M = 1722.94ms, M = 1584.25ms, block 1 to 5 respectively). These results are depicted in *Figure 5.*

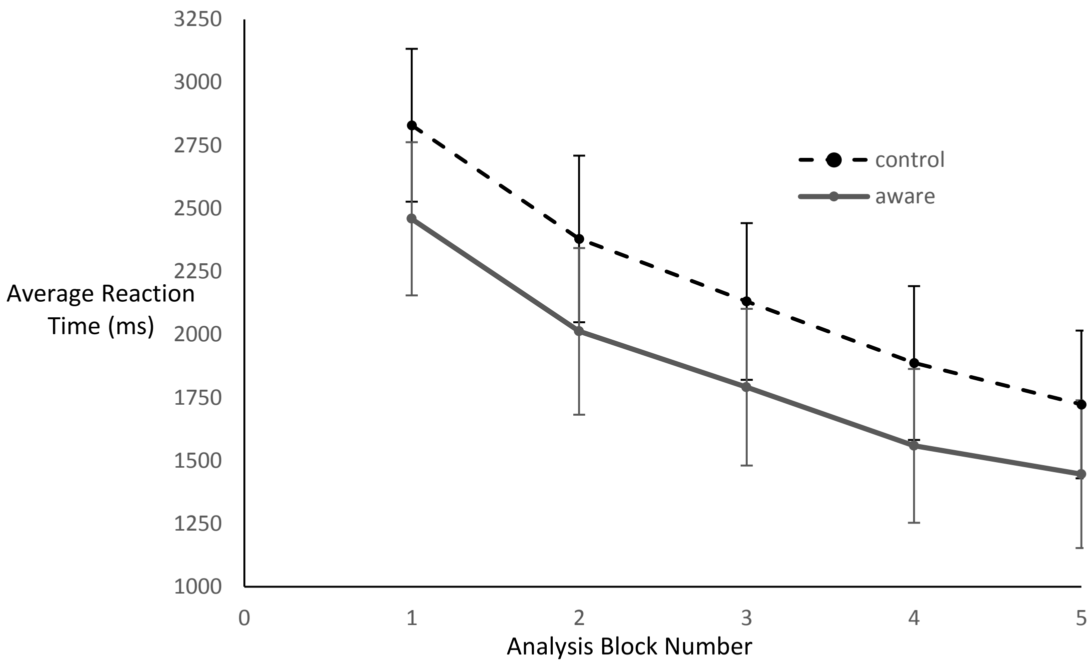

Figure 5. Average reaction time over 5 blocks with 95% confidence intervals.

Comparison of Groups (Slope Values)

Prior research has established that there is a clear linear relationship between numerosity and reaction time (Lassaline & Logan, 1993). Due to this well established relationship, the slope of the linear function of reaction time and numerosity was calculated for each analysis block for each participant. This linear relationship, and the associated slope value for block 1 is depicted in *Figure 6*.

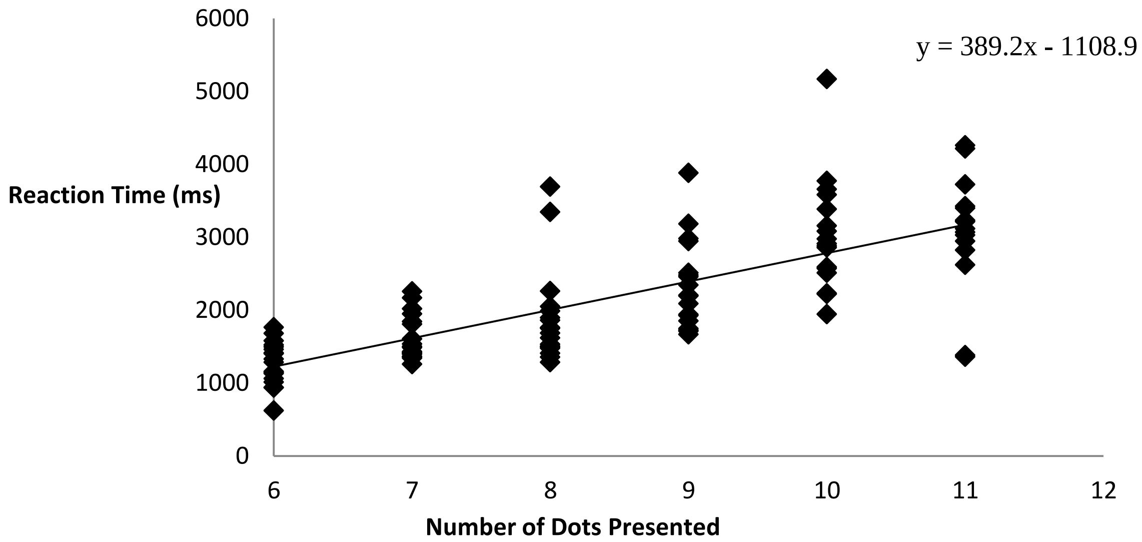

Figure 6. Example linear trend of one typical participant's reaction time as a function of numerosity in experimental block 1, showing a slope value of 389.2 ms/dot.

Mixed Design Analysis of Variance – Slope Values. A mixed design ANOVA examined the slope values for the within-subject effect of practice and the between-subject effect of awareness of repetition. Again due to violation of sphericity the Greenhouse Geisser adjustment was used. This ANOVA showed a significant reduction in slope values over practice, $F(2.84, 90.85) = 28.62$, $p <.00$, no significant difference between groups, $F(1,32) = 2.29$, $p =.14$, and no interaction effect for groups over practice, $F(2.84, 90.85) = .40$, $p =.74$. Pairwise comparisons showed a significant decrease in the slope values between the first, second and third blocks only (M = 229.68ms/dot, M = 138.55ms/dot, M = 66.11ms/dot, respectively).

Effect Size and Confidence Intervals

Effect size and confidence intervals for reaction time data were examined following the insignificant results of the ANOVAs. This was done in order to examine the practical significance of the effect rather than just rejecting the effect based on non-significant statistical results alone (Cumming, 2014). The reaction times for both groups appeared to follow a similar power function, with the aware group showing on average faster reaction times (*Figure 5*). Although reaction times appear to be faster for the aware group, there is no interaction visible, and the size of the group effect on performance is small (partial $\eta^2 = .078$). The 95% confidence intervals support a difference in reaction time between the groups as the intervals of one group do not overlap with the average reaction time of the other group for most analysis blocks (Cumming, 2014). This indicates a difference between groups that was less than 5% likely to result by chance.

Comparison of Time at which Automaticity was Reached

The point at which participants reached automaticity was compared between groups. Reaching automaticity was defined as the block in which the slope of the reaction time by numerosity function reached 100 ms/dot or less. Slope values significantly decreased over practice until approximately reaching 100ms/dot (analysis block 3) after which they did not significantly decrease with more practice. This is depicted in *Figure 7*. This pattern of slope value change is similar to the results found by Lassaline and Logan (1993), with no significant reductions after approximately 100ms/dot. This indicates that automaticity was reached at approximately this value, and the consistent findings from both studies justify the use of 100ms/dot as the definition of when automaticity was reached.

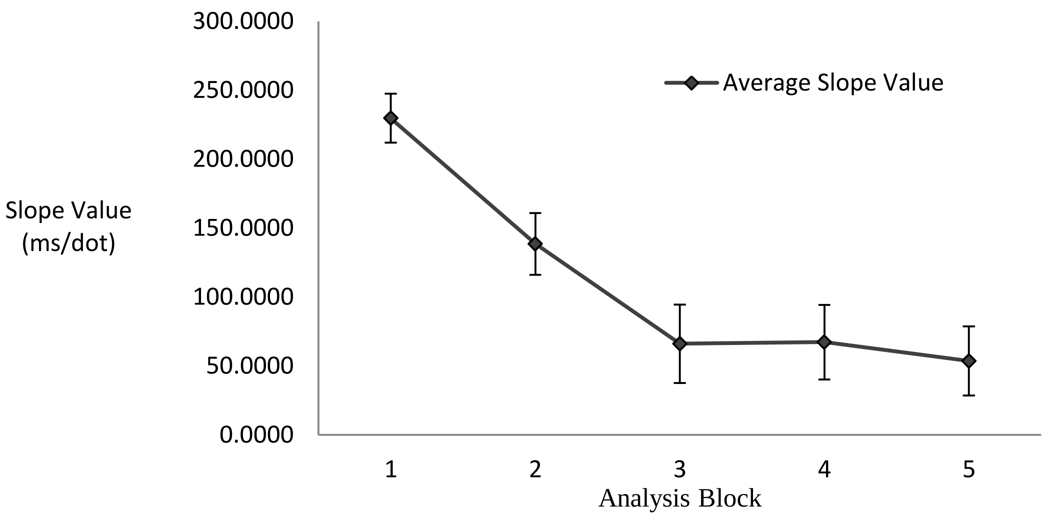

Figure 7. Average slope value change over practice for all participants with error bars representing standard error.

Participants in the experimental group and control groups were compared using 100ms/dot or less the criterion. The experimental block in which they reached this value and therefore automaticity was recorded. All but two participants (one in the aware group and one in control group) reached a slope value of 100ms/dot or less, thus the data for the two subjects who did not reach the criterion was excluded from the analysis. There was no difference found in when automaticity was reached between the two groups (aware group M = 7.125 experimental blocks of practice, control group M = 7.125 experimental blocks of practice) as depicted in *Figure 8*.

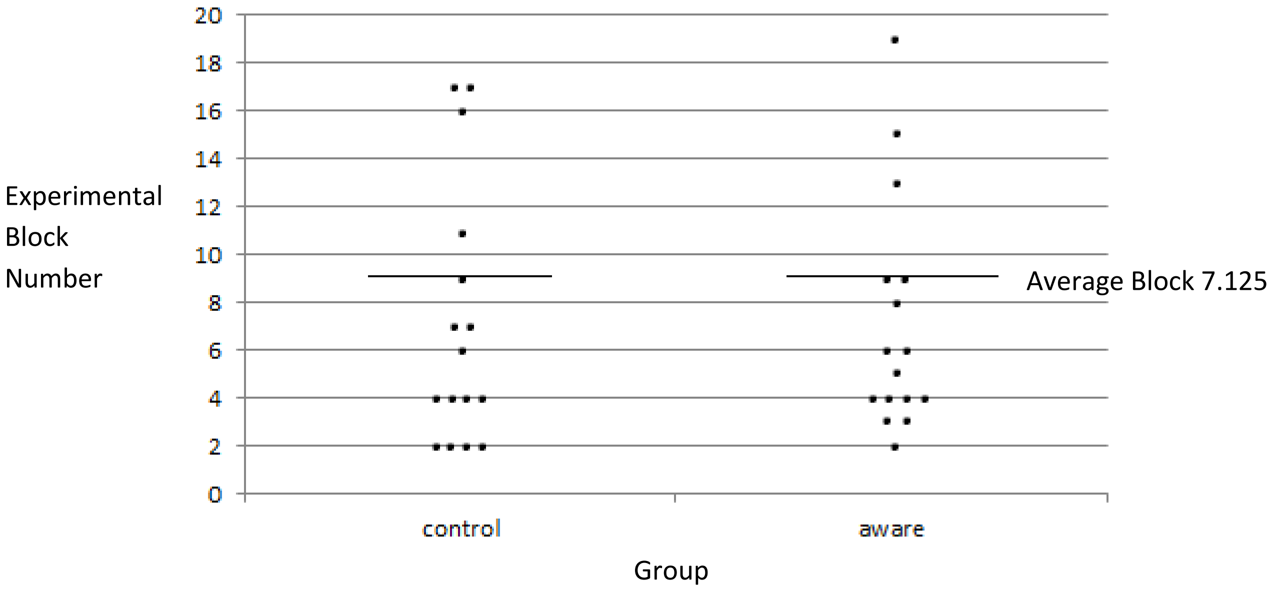

Figure 8. The experimental block number in which participants reached automaticity with a slope of 100 ms/dot or less.

Participants' Awareness. A correlational analysis was conducted in order to review the relationship between when participants thought they reached automaticity (said they learned and used the patterns in the post-experimental interview questions) and when they reached automaticity according to the slope below 100 ms/dot criterion. All participants indicated in the interview questions that they were aware of the repetition and found it helpful to complete the task. Similarly in discussion during the post-test interview all but one participant in the experimental group indicated that they felt being told about the repetition before the task helped them respond quicker. The answers of all participants to the post-experimental questions can be seen in Appendix E. The analysis comparing perceived and actual attainment of automaticity was conducted on the 32 participant's data who reached automaticity only. Pearson correlation coefficients were calculated revealing no correlation between when participants thought they reached automaticity and when they actually did for the experimental group r = .016, p = .95, or the control group, r = .276, p = .30. Following this an independent samples T-test was conducted showing no significant difference for when participants thought they reached automaticity between the aware group (M= 8.82 blocks, SD= 7.65) and the control group (M= 11.76 blocks, SD= 5.86), $t(32) = 1.26$, $p = .217$.

Discussion

Overall results

There appeared to be no significant differences in reaction times between those who were aware of the repetition of pictures before starting the task and those who were not. Similarly the slope value data showed no significant difference in the pattern of slope reduction over practice. Most importantly, the analysis revealed the predicted interaction effect of groups over practice was not observed. This lack of interaction indicates there is no evidence for any advantage of being aware of the item repetition before the task commenced.

Similarly, effect sizes and confidence interval analysis showed a very small effect size for group on performance, indicating the groups reduction in slope value, thus their development of automaticity did not differ by a large amount (partial $\eta^2 = .078$). Interestingly the experimental group appeared to have faster overall reaction times than the control group. This was observed when examining the 95% confidence intervals. These intervals did not overlap in most analysis blocks of practice indicating the difference in reaction times are not likely to occur by chance (less than 5% likely). Although this may be true, there was no interaction effect observed, and given the small effect size the difference most likely occurred by chance even though it was unlikely. Participants in the aware group appeared to already have pre-existing faster reaction times than participants in the control group. Given this pattern of results, the results clearly do not support the prediction that awareness of repetition enables faster development of automaticity and that knowledge of contextual information before commencing the task can impact the speed of its development.

The results also showed that regardless of condition, the participants were not aware of when automaticity had been attained. There was no correlation between when they reported, and when the data showed that automaticity was reached. All participants reported recognising the repetition in the stimuli, but were unable to accurately report when this "helped them perform the task" or reach automaticity. According to memory-based theories, automatic processing occurs subconsciously and without attention (Choplin & Logan, 2005). The results support this view as to the nature of automatic processing.

Comparison to Lassaline and Logan's Study

The overall pattern of results in the current study regarding changes in reaction time over practice is consistent with the results found by Lassaline and Logan (1993). The counting task used in the current study was similar to that used in their research. In both studies the task provided a clear example of the observable difference between when controlled and automatic processing was used for responding. Reaction time in both studies reduced rapidly in the first few experimental blocks, then stabilised at a certain point reflecting the asymptote of maximum performance improvement. This asymptotic level of performance was reached by analysis block three in the current study, and practice block four in Lassaline and Logan's. The pattern of reaction time improvement found in both studies reflects the shape of a power function learning curve (Haider & Frensch, 2002; Logan, 1990).

Both studies report the same linear trend for reaction time across numerosity, with a clear pattern of reduction in slope values. These slope values did not significantly improve beyond approximately 100 ms/dot in Lassaline and Logan's (1993) results as well as the results of the current study. The replicated pattern of results in this study supports the use of slope values for analysing when automaticity has development in simple numerosity tasks.

Both studies yielded similar results further supporting an instance theory explanation of automaticity.

Theoretical Implications

The instance theory (Logan, 1988, 1992; Logan & Klapp, 1991) of automaticity provided the context and grounding from which this study was conducted. The results of this study support the nature of automaticity described by Logan in the instance theory. They also indicate that participants are not aware of when they develop automaticity, and that automatic responding is not subject to the influence of contextual factors outside of task-specific characteristics. The expected advantage of knowing about the repetition of stimuli resulting in faster reductions in reaction time did not occur. Given there was no difference in performance improvement between the experimental and control groups, being aware of the repetition did not provide any advantage. These results are consistent with instance theory as the theory defines automatic processing as requiring no attention, making performance seemingly effortless, fast and unavailable to conscious influence such as directed attention to contextual information. The results of this study supported the theory that automatic responses are based on memory retrieval alone once the task is practiced enough for each stimulus to elicit a response based on recognition.

The slope values reaching asymptote after analysis block 3, with reaction time being equal across all levels of numerosity also supports memory retrieval responding in accordance with instance theory. This is because responding is task-specific and requires only the specific stimuli-response associations in memory for retrieval of instances. In clear support, the results of the current study demonstrated that awareness of the repetition (context) of the task did not change the way in which automaticity developed.

Instance theory also postulates that improvements in performance may occur after automaticity is reached as a result of memory becoming more efficient with further practice (Logan & Stadler, 1991). Consistent with this theory, the results showed smaller improvements after automaticity was reached (slope less than 100 ms/dot) for the remainder of the five analysis blocks. Average reaction times decreased over all analysis blocks of practice, although not to a level that was statistically significant beyond analysis block 3. As the observed changes in reaction time are consistent with that of Logan's work and an instance theory explanation of performance improvements, the current study provides further evidence of instance theory being a valid explanation of automaticity.

No Effect of Awareness

The results clearly support no significant differences in the development of automaticity for the counting task between those who were informed about the repetition of pictures and those who were not. By instructing the experimental group to be aware of the repetition this clearly manipulated the participant's knowledge of the context of the task before it began. Given this was the case, the fact that it provided no advantage means the results can be explained simply by instance theory as previously discussed. The results of this study add valuable information about whether automaticity development can be quickened to the debate surrounding the stability and manipulation of automatic processing through contextual factors.

There has been a continual debate within cognitive psychology research literature challenging the notion that automatic processing is not influenced by context (Augustinova et al., 2010; Dishon-Berkovits & Algom, 2000). Dishon-Berkovits and Algom (2000) suggested context may be attended to during automatic processing resulting in changes to performance in a Stroop task. By changing the likelihood of one type of stimuli being presented, a change in the Stroop effect resulted. Similarly, the Stroop effect can be eliminated or suppressed using spatial cuing in a semantic version (See Labuschagne & Besner, 2015). In both of these cases, the contextual change resulted in an inhibition of a response that was previously believed to be automatic and irrepressible (Labuschagne & Besner, 2015). These researchers propose that attention to the context of the task during automatic processing is important and that automatic processing is not stable across any given context.

This evidence of the influence of contextual information upon developing automaticity can also be seen within numerosity studies. It has been found that by changing the context of a task from numerical magnitude (meaning of the numbers) to numerosity (quantity of numbers), automatic processing of numerical magnitude can be supressed (see Pansky & Algom, 2002). Similarly, this has been shown to occur for changing the context of a task from comparative judgments (bigger or smaller than 5) to parity judgments (odd or even) where automatic processing of numerosity can be supressed (see Naparstek & Henik, 2010). This automatic processing of numerosity (the quantity of items presented) in a stimulus can impact the selection and execution of a response (Miller, 2006). In these studies it appears that the automatic activation of a numerosity response depends upon how relevant the information is to the context of the task that is being completed (Dormal & Pesenti, 2013). The results of the current study are not consistent with these findings as automaticity development did not differ for those who were aware of the context and those who were not. The surrounding literature and the results of this study suggest that contextual change may be able to suppress an automatic response, but cannot influence the way in which automatic processing develops as a process.

Within the experimental Stroop task literature, other research has demonstrated that by changing the spatial cuing or colouring of a Stroop task there is no effect on automatic responding (Augustinova et al., 2010). This finding is consistent with the current study's results, as well as the instance theory explanation of automaticity. Bringing awareness to context, the repetitious nature of the task, did not affect automatic responding as the instances that are relied upon for responding are task-specific (Logan, 1988). These results are consistent with automatic processing being uninfluenced by contextual change.

Although these studies provide some evidence of automatic responding not being stable when contextual information is changed, again they are concerned with inhibiting an automatic response. As such it was proposed in the present study that automaticity could be aided in development by attending to the context of the task before it was performed. Although this seemed a valid proposition, the results did not support this. In fact the results provided evidence that the development of automaticity is a stable process, as reaction times decreased in a similar pattern over the course of practice for both the experimental and control groups. Regardless of awareness of repetition, automaticity developed the same way.

Awareness and Control

Within the literature surrounding awareness of and control of cognitive processing this study has some interesting implications. From a memory-based perspective, it appears there is some evidence of an ability to control the use of automatic or controlled processing during performance of an automatic task (Wilkins & Rawson, 2011). The most common way to observe this is when instructions for speed or accuracy are emphasised. If accuracy is emphasised people tend to continue with controlled processing for much longer, developing automaticity slower. Conversely, if instructions for speed are emphasised people tend to develop automaticity faster, relying on memory retrieval earlier (Wilkins & Rawson, 2011). It has also been demonstrated that when instructed to calculate every answer rather than memorise answers, controlled processing of an automatic task is possible (Fisk & Schneider, 1984). This conscious use of controlled processing to perform a task that was automatic leads to long term memory storage of information that reflect when the task was being originally learned in a controlled manner (Fisk & Schneider, 1984). Given that people exhibit some control over processing type when given different instructions, this suggests that there is a level of awareness and control over which processing type is used for responding. Further investigation regarding the level of awareness people have of the process of developing automaticity was identified.

The results of the current study indicate that the time at which people reported responding on the basis of memory retrieval did not correlate with the point at which their reaction times indicated they had reached automaticity. It is interesting to note that there was no significant difference between the groups regarding when they felt they reached this point. However the experimental group reported that knowing about the repetition in the pre-experimental instructions helped them perform the task quicker. These results indicate that being told about the repetition in the task allowed participants to think they performed better than if they had not been told, even if it made no difference to their performance or awareness of when automaticity developed. In light of this finding and the research discussed above, it appears that control over memory retrieval and use of controlled processing when performing a task is possible, but people are not aware of when the change from controlled to automatic processing occurs. One possible reason for this may be that due to using greater cognitive resources to perform the task in a controlled manner initially, the change to using memory to respond automatically is not noticed. It is speculated that as the focus of participants was to respond as accurately and rapidly as possible, they did not attend to the way in which they completed the task, only to completing it.

Practical Implications

Learning simple mathematical skills such as mental arithmetic has been found to rely on automatic processing (Estudillo et al., 2015). The evidence that number skills develop on the basis of automatic processing with practice is not surprising, as the development of automatic responding for numerosity was demonstrated in the current study. The implications of this study in relation to mathematical skill development relates to being able to influence and aid the development of automatic processes. Given the debate surrounding the influence of contextual factors on automaticity, if being aware of contextual factors aided automaticity development, mathematical skills could be improved by directing attention to patterns in numbers relevant to the nature of the task (Baroody & Ginsburg, 1990). However, the evidence from the current study does not indicate that automaticity can be quickened as a result of this deliberate directing of attention. It is important to note that within the cognitive psychology literature, it is accepted that contextual information may play a role in helping maintain and exhibit automatic responses when relevant to the mathematical task (Miller, 2006; Naparstek & Henik, 2010; Pansky & Algom, 2002). This means that although it appears that there has been no indication of how to speed up the learning process to reach automatization, teaching methods still need to provide the right contextual information in order to aid application of basic skills to more complicated mathematics. Knowledge about context helps integrate new information with the automatized skills students already possess (Baroody & Ginsburg, 1990).

Although there was a steady rate of change from controlled to automatic processing for all participants, people believed knowing about the repetition aided them in the task. Even if this information only provided confidence in the task, and a belief that it helped them perform, this would still be beneficial for learning mathematical skills. It has been found that a positive attitude about performance in mathematics is linked to better performance in school (Eklöf, 2007; Hemmings et al., 2011). Given that mathematics is also evidently linked to the future job success of many students, any attempt to improve attitudes may be beneficial (Chang & Choi, 2011; Hemmings et al., 2011).

Limitations and Future Directions

Several important limitations must be considered during the interpretation and application of the current findings. Firstly, in order to reduce researcher bias, especially because participants were known to the researcher, the instructions for the task were presented on the computer screen for participants to read before commencing the task. This is where the manipulation of the independent variable occurred. One limitation in relation to this was that after participation, a few participants reported having skipped the instructions or not remembering having read them. This was potentially problematic as the manipulation of awareness of repetition may not have occurred in some cases. Despite this, of the four participants reporting not having read the instructions, only one was in the experimental group, thus the manipulation was still considered adequate and any researcher bias in instruction was avoided.

It is also worth noting that in order to reduce the variability within the data, it was reduced from the 30 experimental blocks to the 5 analysis blocks. This was appropriate as it made the pattern of learning and any effects more easily observable. The variability found in the results of this study may have resulted from participants not completing enough experimental trials. If participants had completed more trials per experimental block, the variability could have been reduced by providing more practice and time for automatic processing to develop clearly. Future studies looking at automaticity development should, if possible, have more practice blocks which would reduce variability. This may make the results clearer with more definite patterns of learning visible. Replication with more trials would be beneficial by providing further evidence that automaticity development is not influenced by contextual information.

Future research should be conducted to further understand the way in which automatic processing may be influenced in numerosity tasks. The possibilities that verbal instruction or methods of directing attention to context other than written instructions may influence automaticity development have yet to be explored. There has been limited research into the types of contextual information that is needed to initiate, inhibit or influence automatic processing. If such information is important to attend to during a task, what aspects of the context are stored in memory representations? The debate surrounding contextual influence is still ongoing, and although it has already been established that specific task characteristics are stored in memory as instances, what, if any contextual characteristics are stored is still unclear.

Finally further research should be conducted in applying this knowledge about automaticity to mathematical skills. As mentioned previously even if contextual awareness aided attitudes towards mathematics and allows better integration of knowledge for children learning basic mathematics, ability in this area may improve. This follows on from the observation that the participants in the study believed knowing about the repetition helped them perform the task better, even if it made no apparent difference to their reaction time. This should be further investigated for future applications in teaching methods.

Conclusion

The purpose of this study was to investigate whether bringing awareness to contextual information can improve the speed at which automaticity developed. Given the evidence that context can influence the exhibition of an automatic response, it was hypothesised that prior awareness of this information could also aid the speed of developing automatic processing.

The results demonstrated that this was not the case. The current findings suggest no advantage resulted from being aware of the repetitious nature of the task before learning began, and that the rate of developing automatic processing was constant regardless of being aware of the context or not. These results are consistent with Logan's (1988, 1990) work and an instance theory explanation of automaticity. Development of automaticity being immune to the influence of contextual information is consistent with instance theory which postulates automatic processing being an unconscious process requiring no attention. The results of this study added clarifying evidence about the role of contextual information in automatic processing.

This study was potentially limited by the variability found in the data as a result of not having enough practice trials in each experimental block. Although this was overcome by reducing the number of blocks for analysis to increase clarity in the results, future studies should examine the numerosity task with more practice trials. Similarly, as some participants reported not reading the instructions alternate methods of providing the contextual information should be considered. Further benefit would be gained by investigating different types of contextual information, in order to establish if any of it is stored in memory as instances. Even though these results indicate no benefit is gained in performance by providing knowledge of the repetition in the task, participants felt that knowing about the information before performing the task provided some benefit. In relation to mathematical education, if knowing the nature of the task by having attention directed to the context in which it needs to be performed helps boost the confidence of students and attitudes about mathematics a positive improvement in mathematical skill could result. Further research should be conducted to investigate this possibility in an educational setting.

In conclusion, this study is consistent with Logan's work, and the instance theory explanation of automaticity. It appears that the speed of developing automatic processing in a numerosity task is not influenced by pre-awareness of repetition of stimuli. This study helped provide clarifying evidence in the ongoing debate about the stability of automaticity across different contexts, supporting the well-known characteristics of automatic processing.

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Appendix A: Information Letter

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Automatic or Deliberate - How do you learn?

Join the dots

Faculty: Health Engineering and Science

School: Psychology and Social Science

Contact Information:

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Supervisor: Craig Speelman

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Project Description:

This project investigates the way in which we acquire skills used in everyday life. When we practice a task many times the response can sometimes become automatic. This project will look into how we pay attention to simple tasks during this learning process. It will also potentially help to improve future teaching techniques in many educational settings. You are invited to participate as a representative of the general population.

Participation:

Participation in this research project is voluntary. You may withdraw from the project at any time with no explanation needed, and you may choose not to participate at all with no consequence. Participation in the project will require you to attend one session at Edith Cowan University's Memory and Cognition laboratory. The session will involve a simple counting task performed on a computer which will take approximately 1 hour of your time. The timing of your session will be at your convenience. There will be optional break periods during the experiment.

The information which will be generated from this project will only be used for this projects research, and will only be accessed by Emma Shadbolt and Craig Speelman. Once the data from your results is collected there will be no personal information to identify you within the results, making it anonymous for the analysis and reporting in the thesis. The information will be stored within the laboratory's archive system after the completion of the project.

Questions/ Further Information:

For any questions regarding participation or the research project you may contact Emma or Craig whose details are at the top of the page.

Alternatively if you have any concerns or complaints about the research project and wish to talk to an independent person, you may contact:

Research Ethics Officer

Edith Cowan University
270 Joondalup Drive
JOONDALUP WA 6027

Phone: (08) 6304 2170
Email:
research.ethics@ecu.edu.au

Appendix B: Consent Form

EDITH COWAN UNIVERSITY AUSTRALIA
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Automatic or Deliberate - How do you learn?

Join the dots

Faculty: Health Engineering and Science

School: Psychology and Social Science

Contact details:

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No: 0448 018 906

Supervisor: Craig Speelman

c.speelman@ecu.edu.au

No: 6304 5724

I _________________________ give consent that I:

- have received a copy of the information letter
- have read and understood the information letter provided.
- have been given the opportunity to ask questions and receive answers to these questions to my satisfaction.
- understand my participation in the research will involve completing a counting task on a computer screen in the Memory and Cognition laboratory taking approximately 1 hour.
- understand that the information provided will be kept confidential, and that my identity will not be disclosed without consent.
- understand that the information provided will only be used for the purpose of this research project.
- understand that I may withdraw from further participation at any point in time, without explanation or penalty.
- that upon signing this form I am freely agreeing to participate in this project.

Signature: ________________

Appendix C: Instructions and Post-Test Questions

Instructions on the computer start screen for participants:

Control Group:

"The task will require you to watch the computer screen and indicate the number of dots shown on the screen as accurately and quickly as possible. Use the response box provided with the corresponding keys."

Experimental Group:

"The task will require you to watch the computer screen and indicate the number of dots shown on the screen as accurately and quickly as possible. Use the response box provided with the corresponding keys. You should be aware that the dot patterns will be repeated many times in the experiment."

Post-Test Questions:

Control Group:

1. "Did you notice the repetition of the patterns of each number of dots?" (If response is "No", ask no further questions. If response is "Yes", ask question 2)
2. "Did you find that the repetition of the pattern for each number of dots helpful?" (If response is "No", ask no further questions. If response is "Yes", ask Question 3)
3. "At what point did you find the repetition helpful during the 30 blocks of trials? Can you give an estimate of the block number?"

Experimental Group:

1. “Did you find knowing about the repetition of the patterns helpful during the task? (If response is “No”, ask no further questions. If response is “Yes”, ask Question 2)
2. “At what point did you find the repetition useful during the 30 blocks of trials? Can you give an estimate of the block number?”

Appendix D: Pictures used for each Number of Dots

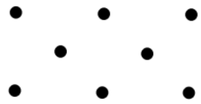
Practice Stimuli			
			
6 dots	7 dots	8 dots	9 dots

Table1. Practice Stimuli used in the initial four practice trials.

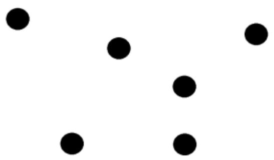
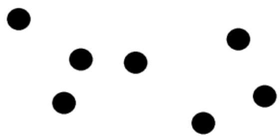
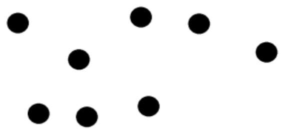
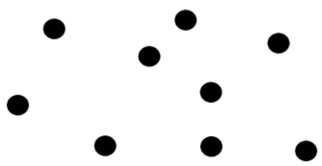
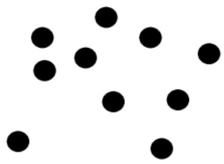
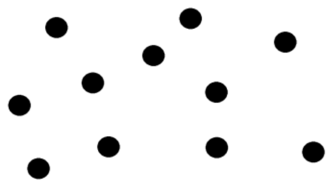
Experimental Stimuli		
		
6 dots	7 dots	8 dots
		
9 dots	10 dots	11 dots

Table 2. Experimental Stimuli used in the 30 experimental blocks.

Appendix E: Participant's Reponses to Post-Test Questions

Participant	Group	Qu. 1 (Control group only)	Qu. 2	Qu. 3
1	Experimental	-	yes	1
2	Experimental	-	yes	1
3	Experimental	-	yes	4
4	Experimental	-	yes	3
5	Experimental	-	yes	1
6	Experimental	-	yes	15
7	Experimental	-	yes	1
8	Experimental	-	yes	20
9	Experimental	-	yes	15
10	Experimental	-	yes	20
11	Experimental	-	yes	18
12	Experimental	-	yes	7
13	Experimental	-	yes	20
14	Experimental	-	yes	10
15	Experimental	-	yes	2
16	Experimental	-	yes	10
17	Experimental	-	yes	2
18	Control	yes	yes	3
19	Control	yes	yes	15
20	Control	yes	yes	4
21	Control	yes	yes	5
22	Control	yes	yes	20
23	Control	yes	yes	15
24	Control	yes	yes	15
25	Control	yes	yes	3
26	Control	yes	yes	10
27	Control	yes	yes	15
28	Control	yes	yes	10
29	Control	yes	yes	5
30	Control	yes	yes	15

31	Control	yes	yes	20
32	Control	yes	yes	12
33	Control	yes	yes	15
34	Control	yes	yes	18

Table 3. Participant’s responses to post-test questions during interview.