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The relationship between working memory capacity and movement memory of dancers

Katrina Louise Muller-Townsend
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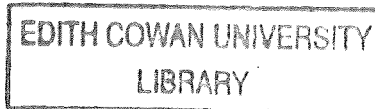
A report submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Arts (Psychology) Honours, Faculty of Computing, Health and Science, Edith Cowan University.
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The Relationship Between Working Memory Capacity and Movement Memory of

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Abstract

Working memory capacity span tasks are suggested to predict complex cognitive behaviour across varied domains (Conway et al., 2005). However, it has been criticised that expert skills are highly situational and domain specific (Marteniuk, 1974). The current research aimed to investigate whether general memory span was related to movement span, and furthermore, whether this can predict dance learning. It was expected that memory for movement would be positively correlated with measures of working memory, due to the specific components of working memory, such as the capacity of the phonological loop. Furthermore, it was expected on the basis of previous research (e.g., Starkes, Deakin, Lindley & Crisp, 1987) involving the serial position accuracy of dance items, that there would be a demonstration of serial position of movement recall that is different to the general serial position curve (Murdoch, 1962). Data was collected from 30 dancers from the Western Australian Academy of Performing Arts. Results supported the hypothesis that memory for dance movement would be positively correlated with general measures of memory span and that only primacy effects would be observed in the serial recall of dance movement. Consequently, it was proposed that verbal span measures may be able to predict something about the nature of an expert dancers ability to recall new dance steps due to an enhanced rehearsal mechanism. It is suggested that further research is required to investigate the complexity of the working memory theory in relation to movement memory to provide a better understanding of memory and learning processes.

Katrina Lousie Muller-Townsend

Professor Craig Speelman

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The ability of an experienced dancer to remember numerous movements in succession is not only of interest to expert dancers who may wish to improve learning and memory strategies, it also poses an interesting challenge for the psychological theory of working memory (Smyth & Pendleton, 1989). A large proportion of the research into the processes and structure of human movement memory has focused on the differences between novice and expert dancers' ability to recall a series of dance movements (referred to as movement span) (Smyth & Pendleton, 1989). More recently, the focus of studies on movement has broadened to include those components of memory for dance movements that may reflect abilities assessed by general measures of memory capacity (Starkes, Deakin, Lindley & Crisp, 1987; Stevens & McKechnie, 2005).

Previous research has shown that expert dancers' movement spans are larger than that of non-dancers for both dance movement and nonsense movement (Smyth, Lindsay & Pendleton, 1987; Smyth & Pendleton, 1994; Starkes et al., 1987). Specifically, immediate recall for movement elements demonstrates improved encoding and retrieval of movements in general for expert dancers, compared to their novice counterparts. However, previous studies involving expertise in domains such as chess (e.g., de Groot, 1966) has identified that memory superiority is affected by domain specific form, rules and regulations. Although dance involves its own set of sequence rules and physically possible movement choices, when these rules are removed (as in nonsense movements), expert dancers still seem to perform better in recall of these movements compared to novice or non-dancers.

Despite the increasing breadth of research into the various relationships between dance movements and span, investigation into what separates effective learners within particular domains of expertise (specifically, which aspects of working memory can predict effective and efficient learning) is notably absent in the literature. Therefore, the current study aimed to investigate whether general memory span is related to movement span, and furthermore, whether this can predict dance learning. The following sections discuss past and present research involving expertise in terms of domain specificity and how this currently relates to measures of working memory and working memory components. This paper proposes that memory for movement (specifically, dance movement) may be related to measures of working memory due to the specific components of working memory such as the capacity of the phonological loop. Specifically, it is suggested that verbal span may be able to predict something about the nature of an expert dancer's ability to recall and learn new dance steps due to an enhanced rehearsal mechanism.

Expert Memory and Domain Specificity

Examples of expert memory have been observed in digit span (Chase & Ericsson, 1982), dinner orders (Ericsson & Polson, 1988), and mental calculation (Staszewski, 1988). A frequently cited example is that of chess masters, who have been observed to reproduce 20 or more positions on the chess board after a five second glimpse mid-game (de Groot, 1966). Surprisingly, de Groot (1966) found that this level of memory superiority was removed when chess pieces were arranged on the board at random, suggesting that this type of expertise is non transferable to non-game scenarios and is predominantly domain specific.

In support of de Groot's findings, Marteniuk (1974) also hypothesised that skill acquisition is situationally specific. Thus, an individual who demonstrates strong

abilities in a number of different areas such as sports happens to possess a large number of independent abilities that are characteristic of each sport. Furthermore, this hypothesis has been supported by findings in other domains of expertise. For example, one mnemonist named Finkelstein, investigated by Sandor (1932) and Weinland (1948), used his knowledge of the properties of numbers to remember digit strings. His visual digit span was reported to be 39 and his auditory digit span was 20. He would visualize digits written in his own handwriting on a mental chalkboard; however, this was limited to only digit stimuli. His letter span was average and his memory for visual forms was below average.

It is a common finding that such experts can recall greater material from their domain of expertise, compared to their novice counterparts. This is suggested to be attributed to experts' greater knowledge of effective memory strategies, such as higher order groupings in material enabling effective recall of material as one unit (Smyth & Pendleton, 1994). An expert in a given domain of activity, such as medicine, chess, music or golf, is one who has acquired special skill in or knowledge about a particular subject through professional training and practical experience (Marteniuk, 1974). Experts will therefore have a greater body of knowledge about their domain of expertise than other individuals. More remarkable is the experts' accurate memory for new experiences in their domain. For example, an elite athlete can, after a sports event, discuss the play-by-play action, and expert chess players can readily recall details of chess positions from their matches in recent tournaments.

This raises the question of whether extraordinary memory abilities are attributed to exceptional or 'superhuman' abilities, or, the adaptation of effective memory strategies shaped and developed over time through deliberate practice in a particular domain (Marteniuk, 1974). It was previously thought that experts were innately talented

with a superior ability to store information in memory. However, more recent research has rejected this hypothesis of a generally superior memory in experts and has demonstrated that experts' superior memory is limited to their domains of expertise and can be viewed as the result of acquired skills and knowledge relevant to each specific domain (Marteniuk, 1974). This was demonstrated by Chase and Simon (1973), who showed superior memory for chess positions by chess experts that reflected such acquired specific skills and knowledge of chess.

Chess players ranging from beginners to international masters were shown a position from an actual chess game for a brief time (normally 5 seconds) and were then asked to recall the location of all the chess pieces (Chase & Simon, 1973). The ability to recall increased as a function of chess skill. Beginners at chess were able to recall the correct location of about four pieces, whereas international-level players recalled virtually all of the more than twenty pieces. To rule out the proposal that the superior memory of chess experts reflects a general superior ability to store any kind of visual information, Chase and Simon (1973) had chess players recall chessboards with randomly placed pieces. With briefly presented random chessboards, players at all levels of skill had the same poor recall performance and were able to recall the correct location of only about four pieces, a performance comparable with that of chess beginners for actual positions from chess games.

Furthermore, when actual chess positions were shown using an unfamiliar notation, the chess expert was able to display a similar level of superior memory performance after a brief period of adjustment (Chase & Simon, 1973). This result suggests that the superior memory of experts is not photographic and requires arrangements of chess pieces that can be encoded using associations to the experts' extensive knowledge of chess. Since Chase and Simon's (1973) study, investigators

have shown expertise in areas such as computer programming, basketball and dance is related to superior memory performance for meaningful stimuli in the associated domain, and that this superiority is mediated by increased knowledge and domain-specific skills (Ericsson, Patel & Kintsch, 2000).

Although previous research has investigated the specificity and generalisability of expertise, there is a lack of investigation into what separates effective learners within particular domains of expertise. For example, in the area of motor expertise research has been conducted involving dance experts that supports much of what we already know about expertise; that dancers demonstrate extraordinary memory abilities and that this extraordinary ability changes when taken out of the context of dance recall (i.e., nonsense movement vs. dance movement). For example, a study by Starkes et al. (1987) found that choreographed ballet sequences were better recalled by expert ballet dancers than unchoreographed nonsense ballet items. This typically demonstrates similar findings previously mentioned in the case of chess experts (Chase & Simon, 1973). When experts are taken out of their specific domain situations superior memory is reduced. This raises some specific questions concerning the acquisition of skill; firstly, if skilled memory is defined as domain and situationally specific, what role does memory play in the learning of skilled expertise. Secondly, how is skilled memory related to working memory abilities? Thirdly, what can working memory capacity tell us about how expert skill is acquired or maintained? In order to investigate the relationship between memory capacity and expertise such as movement recall in dance, the concept of working memory needs to be considered in terms of its structure and how its components relate to skilled memory.

Working Memory Theory

Working memory is a theoretical construct in cognitive psychology of the structures and processes used for temporarily storing and manipulating information in short-term memory and the manipulation of incoming information. There are many theories and varied opinion of what "working memory" consists of and how it is used in the learning process. For example, Atkinson and Shiffrin (1968) proposed that information selected by a person's attention from sensory memory would move into working memory, often termed short-term memory. This would allow people to retain information long enough to use it; for example, looking up a telephone number and remembering it long enough to use it, or remembering the sentence that they have just read long enough to connect it to the next one. Peterson and Peterson (1959) demonstrated that information in short-term memory lasts approximately 15-30 seconds, unless people rehearse the material at which time it may be committed to long-term memory. Conrad (1964) suggested that short-term memory is mostly acoustically encoded memory but can also retain visuo-spatial images. The most influential theory of working memory and thus, the theory that has been most used to understand expert memory, was originally proposed by Baddeley and Hitch (1974) and then was later updated by Baddeley (2000). This theory proposes that working memory consists of four components; the central executive, the phonological loop, the visuo-spatial sketchpad, and the episodic buffer.

Components of Working Memory

Baddeley and Hitch (1974) proposed that there are two "slave systems" responsible for the supervision of information, integration and for coordinating the slave systems. The first system the phonological loop stores phonological information (i.e., sound of language) and prevents its decay by continuously articulating its contents,

thereby refreshing information in a rehearsal loop. For example, a seven-digit telephone number can be maintained for as long as one repeats the number to oneself over and over. The second system the visuo-spatial sketchpad stores visual and spatial information and can construct and manipulate visual images and represent mental maps. This sketch pad can be further broken down into; the visual subsystem dealing with shape, colour, and texture, the spatial subsystem responsible for spatial location, and the central executive system which directs attention to relevant information, suppressing irrelevant information and inappropriate actions, and for coordinating cognitive processes when more than one task must be done at the same time (Baddeley and Hitch, 1974). An additional component the episodic buffer has been proposed by Baddeley (2000) to hold representations that integrate phonological, visual, and spatial information and possibly information not covered by the two main slave systems (e.g., semantic information, and musical information). This component is episodic because it is assumed to bind information into a unitary episodic representation for temporary storage (Baddeley, 2000).

Working Memory as a Limited Capacity Store

Working memory is considered to have a limited capacity. Miller (1956) suggested that adult working memory has capacity of around seven elements, regardless of type of information (i.e., digits, letters, words, etc.). Research later revealed that working memory span is not based simply on the number of individual digits that can be held (and subsequently recalled), but rather on the number of chunks of information that can be held and recalled (Tulving & Patkau, 1962). Therefore, grouping (or chunking) information increases memory span. It was found that the average memory span is approximately seven 'chunks' and that span does depend on the category of chunks used (span is usually seven for digits, six for letters and five for words) and even

the features of chunks within the category. For example, span is suggested to be smaller for long words than short (Tulving & Patkau, 1962).

In general, memory for verbal contents (digits, letters, words etc.) based on the phonological loop component of working memory strongly depends on the time it takes to speak the contents aloud (referred to as subvocal rehearsal), and on the lexical status of contents (whether words are known or not) (Hulme, Roodenrys, Brown & Mercer, 1995). Most adults can repeat about seven digits in correct order. Some individuals have shown impressive enlargements of digit span up to 39 digits (Weinland, 1948). This is possible with extensive training on an encoding strategy by which digits in a list are grouped (usually in groups of three to five) and encoded as one single chunk or unit. To do so, one must recognise the groups as some known string of digits.

For example, "SS" and "DD", investigated by Chase and Ericsson (1981; 1982) learned to increase their memory span from 7 to 80 digits with 200-300 hours of practice. As they were both long distance runners they reportedly utilised this experience by encoding digits as running times. Notably this ability did not transfer to memory for word lists or letters. It is suggested that both these individuals were able to relate the strings of digits to already accumulated knowledge invoking rich encoding and providing a greater comprehension base for complex series of input (Smyth et al., 1987). Several chunks could be combined into a higher-order chunk, thereby forming a hierarchy of chunks. Only a small number of chunks at the highest level of the hierarchy must be retained in working memory. At retrieval, the chunks are unpacked again. That is, the chunks in working memory act as retrieval cues that point to the digits that they contain (Ericsson, 1996).

This effect of chunking found in Miller's (1956) studies, supports theories that there is no limit to working memory capacity (Ericsson, 1996; Ericsson & Kintsch,

1995). For example, in his work on working memory, Ericsson (1996) takes the view that working memory capacity can be increased by use of appropriate strategies, and that chunking is merely one simple method of doing so. Although 'chunking' clearly increases working memory span (and therefore hints that capacity can be increased), the fact that Miller found there to be an average span amongst his participants, indicates that there is an average limit on the capacity of working memory, in the absence of training strategies. Therefore, practicing memory skills do not appear to expand general working memory capacity. This is demonstrated by using different retrieval materials (i.e., words, letters). Therefore, as in the case of "SS" and "DD" who could recall up to 80 digits, their expert memory ability was not exceptional when it came to recalling words (Chase & Ericsson, 1981; 1982). Thus, the working memory theory suggests that expert memory involves expertise of specific memory strategies that do not appear to transfer to all memory tasks. However, memory span, as indicated by performance on span tasks is suggested to predict performance on other cognitive tasks (Turner & Engle, 1989).

Evidence of Span Tasks Predicting Performance of other Cognitive Tasks

Since working memory can be described as a system of various components that are responsible for the active maintenance of information during processing, it is suggested that this ability to maintain information is the result of acquired general task aspects (referred to as domain general attention) and specific task strategies (domain-specific skills) (Conway et al., 2005). Conway et al. (2005) further suggest that memory span tasks can predict complex cognitive behaviour across domains such as reading comprehension, problem solving and reasoning and complex memory functions, due to the general executive attention demands, rather than domain specific demands (Turner & Engle, 1989). For example, a novice chess player relies on general executive

attention demands such as recent moves or future positions to maintain game information rather that domain specific skills such as learned strategies and position patterns due to their lack of 'domain' experience. General attention demands are argued by Turner and Engle (1989) to possess similar constructs across differing tasks (such as memory span tasks) that tell us something about the nature of working memory and thus, the nature of cognitive functioning.

As working memory capacity is suggested to involve domain-general executive attention (as proposed by Turner & Engle, 1989), there seems to be no distinction between verbal working memory capacity and spatial working memory capacity (or any other domain). Kane et al. (2004) found that verbal working memory span tasks such as counting, operation and reading span, load on the same factor in a factor analysis as working memory span tasks that demand spatial processing and storage. Furthermore, Turner and Engle (1989) hypothesised that working memory capacity is independent of the specific nature of a task, and hence represents a general resource that is used to perform all cognitive tasks. Therefore, they were able to successfully predict reading ability with a working memory span task that did not involve the reading of sentences. Working memory is of interest in the current investigation as it is suggested to rely on primarily domain general executive attention regardless of the specific types of working memory capacity (i.e., verbal and spatial). Furthermore, as there is evidence to suggest that memory span tasks can predict complex memory functions (Turner & Engle, 1989), it is of interest how span tasks can relate to recall performance of motor expertise such as dance, as dance involves aspects of problem solving, spatial processing and verbal comprehension abilities of an already accumulated language base specific to dance (Stevens & McKechnie, 2005). The current investigation tested this hypothesis by

examining whether general measures of working memory can predict memory-processing components in motor expertise such as dance.

Highly Developed Long Term Memory for Domain Information Assists Memory Performance

Information that is successfully processed through working memory is held in long-term memory. In contrast to working memory, long-term memory is immeasurably large with no known limits (Newell & Simon, 1972). Awareness of the size and importance of this cognitive structure originally came from research into problem solving expertise, an area initially not thought to be directly related to long-term memory. Research by de Groot in the 1940's, demonstrated that the major difference between expert and novice chess players was not superior search moves or larger working memories, but instead, the experts enormous store of real game configurations held in long-term memory (Chase & Simon, 1973).

Chess experts can recognise most of the configurations encountered in a typical game by drawing on their huge bank of stored board configurations and consequently are aware of the best move associated with each particular configuration. Replication of the research by de Groot, in a range of problem solving areas (e.g., Egan & Shwartz, 1979), indicates that long-term memory plays a crucial role in higher intellectual behaviour. In the current investigation it is suggested that dance memory is related to superior memory because of experience (Stevens & McKechnie, 2005).

Equivocal Relationship Between Span and Memory Performance of Experts

In contrast to the previously mentioned literature in areas such as digit or letter string recall indicating domain specificity of expertise (Chase & Ericsson, 1981;1982) the area of music expertise appears to demonstrate enhanced recall in additional areas of memory ability. For example, a study by Chan, Ho and Cheung (1998) demonstrated

verbal memory advantage for musicians who had six years of training compared to individuals with no music training. The participants were presented with a list of 16 words read aloud three times. They then had to recall as many of the words as possible. Results indicated that musicians had significantly higher recall scores than non-musicians. A study by Franklin et al. (2008) also demonstrated greater verbal working memory in musicians. The link between music training and verbal memory of musicians and non-musicians was investigated using reading span tasks and operation span tasks. It was found that musicians had superior performance due to an enhanced rehearsal mechanism. In addition, Tierney, Bergeson and Pisoni (2009) investigated the possible link between music training and immediate memory span. Experienced musicians and three groups of non-musicians were tested. Musicians had longer immediate spans on auditory presentation. However, no difference was reported in visual presentation of a word familiarity test.

In the aforementioned examples of expert memory, the rehearsal process appears to be an important factor related to the phonological loop for storage and retrieval of verbal information. Perhaps in the area of music expertise individuals appear to demonstrate memory abilities that extend beyond music due to their enhanced verbal processing component of working memory. Specifically, rather that enhanced memory strategies such as 'chunking', music experts may be simply well practiced at the rehearsal process. Therefore, capabilities of experts are seemingly more related to different working memory components than one would have thought based on research of domain specificity. As memory for movement involves the recall of sequences, this questions whether memory ability is related to the capacity of the phonological loop (as measured by typical verbal span tasks). In other words, can verbal span predict the

ability to recall and learn new dance steps? Specifically, do dancers use the

phonological loop or some other unspecified component of working memory?

The Working Memory Theory and Movement Recall

Research examining Baddeley and Hitch's (1974) working memory theory has

focused on processes involved in the production and perception of language and spatial

processing. To date movement (specifically, dance movement) has not been of direct

interest. However, it has been suggested that the visuo-spatial scratch pad includes a

specialised subsystem for manipulation of spatial information (Baddeley, 2000) and this

system involves motor processes. This provides a difficulty for the theory of working

memory, as memory for movement may in fact involve different processes from those

used in spatial tasks and there may be a need for a subsystem of working memory that is

specific for movement configurations (Smyth et al., 1989). There is clearly some

confusion as to how movement is involved in spatial processing. Therefore, the current

investigation examined movement memory and working memory capacity as a general

source of information processing relating to learning and memory. Hence, working

memory capacity was considered as involving domain-general executive attention in

order to identify comparisons between movement memory and working memory span.

Dance movement recall is a particularly complex component of the theory of

movement due to its individual components. Thus, research is needed to shed light on

some questions of movement expertise. For example, what parts of memory are used to

remember movement, the visuo-spatial- scratch pad, the phonological loop or a separate

store? As movement for recall can be presented as either phonological information, or

as spatial configurations for imitation this proposes a problem when identifying which

slave system under the Baddeley (2000) theory is responsible for storage, recall and

manipulation of movement material. Although movement involves spatial manipulation,

an expert dancer will have stored these movements as an automatic function and therefore require only the recall of the actual sequence not the individual position within space (Stevens & McKechnie, 2005).

When people are presented with visual information needed to carry out a task, or to reproduce (through imitation), there are several ways in which they can deal with it. One is to maintain a version of the visual input that is used to general subsequent responses; others involve translating the input into a more alternate form-either abstract to one that is specific for particular output. For visually presented words or digits we transform it by subvocalizing. Hitch (1984) suggested that motor processes are involved when we attempt to maintain visuospatial information. The reproduction of visual information that is the movement of a human body (i.e. imitation) has not been investigated in terms of how information is maintained or how this relates to short-term memory and memory span measures.

Movement Memory Capacity

Smyth and Pendleton (1994) investigated movement memory span of ballet dancers compared to non-dancers for movements that were not specific to ballet or any other dance style, that did not make up a coherent sequence, and had no convenient verbal labels. Specifically, they were interested in identifying whether experts in movement are expert in encoding individual movement items unfamiliar to them that do not occur in meaningful units. They utilised two types of movement items; nonsense items and ballet items. Both the novice participants and the experts were assigned to either remembering the nonsense or ballet items. During the learning phase the movement sequences were demonstrated three times and participants were then asked to recall as many items in any order. This was repeated until participants could recall all

items from the set on three successive trials. Movement span was then measured under three conditions; normal span, movement suppression and verbal suppression.

Smyth and Pendleton (1994) found that expert dancers produced longer movement spans than non-dancers even when movements had no distinct meaning and were not part of the traditional ballet vocabulary. It was noted that due to the lack of higher order structure and groupings between the dance steps, neither chunking nor patterned relations between movements are a satisfactory explanation for such superior learning and memory. Increases in movement span were considered very small in comparison to those found in experts such as mnemonists who could utilise specific learning strategies such as chunking. Smyth and Pendleton suggested that this might simply reflect individual differences of human recall. However, given that movement memory is so complex, there may be additional factors that impact on recall results.

In investigating the movement memory span of dancers Starkes, Caicco, Boutilier and Sevsek (1990) discovered differing results to previous movement research (such as Starkes et al., 1987). It was found that expert jazz and modern dancers did not recall more from a sequence of movements that followed Laban's principles (i.e., movements that followed some form of dance rules without choreography), than they did from a sequence that did not follow the principles. Starkes et al. (1990) suggested the specific training of jazz and modern dancers that constitute a purposely-random movement selection of choreographed sequences may have impacted on the results. Jazz and modern dancers are more accustomed to learning and remembering random movement, in contrast to classical ballet where movement possibilities are reduced according to a hierarchy of movement. However, further analysis of the recall of expert versus novice participants found that both structured and unstructured movement produced higher recall overall in experts than novice participants. Therefore, the

experts' memory performance was still better than the norm and thus recall was not

reduced to that of a novice participant as has been found with expert chess players when

taken out of their realm of expertise.

Implications of Movement Expertise

As previously mentioned, expertise such as dance differs to other areas of

expertise due to the factor of movement selection. Specifically, dance involves

choreographed movement that reduces the possibility of particular movement selection

and also implicates the direct nature of assessing movement recall. Through the learning

of items over a dancer's career, individual units of movement may be chunked and

coded to be reproduced based on prior 'choreographical' knowledge of possible

movement selection. Thus, recall may not be based on purely immediate presentation of

movement material, but on prior knowledge of item sequence (Smyth & Pendleton,

1994).

As choreography reduces random movement selection in classical ballet, this

may in fact function in the same way that sentence structure constrains the probability

of particular words appearing in particular orders (Smyth & Pendleton, 1994). In a

ballet technique class, an experienced dancer will pick up a series of movements much

quicker than a novice participant, perhaps due to the higher order groupings of

movements that implies an implicit rule of certain movement probability. For instance,

the expert can code these individual movements, label them, and recall a series of verbal

instructions, because they have built up a knowledge base of similar movement. Their

recognition of new movements as being familiar could be used to reproduce the

movements (Smyth & Pendleton, 1994).

Furthermore, an important factor that may affect an expert dancer's movement

span is the actual movements involved in the dance sequence to be recalled. For a

superior span to be demonstrated, similar to that with mnemonists (e.g., JC), the artificial experimental condition and the specific movements chosen need to be considered. For example, Smyth and Pendleton's (1994) study of expert ballet dancers utilised an experimental instructor that had several years of dance experience prior to working in psychology (Smyth & Pendleton, 1994). However, she was not considered an expert choreographer or dancer. Therefore, the movement elements requiring recall may have lacked true meaning and the hierarchical pattern that is typical to the movement choreography of expert dancers. Thus, results indicating a dancer's movement span as superior regardless of choreography may not be a true representation of a dancer's movement span.

Furthermore, the small improvement in movement span reported by Smyth and Pendleton (1994) conflicts with reports from Allard and Starkes (1991) who observed an adult principal dancer from the National Ballet Company who, after one demonstration of a dance sequence, was able to perform a 96-step sequence followed by verbal labelling marking the steps. Smyth et al. (1994) argued that this demonstration might have resulted from the dancer experiencing a similar sequence at some earlier time. However, the aspect of real situational meaning through choreography must be considered. Specifically, research involving an artificial experimental condition that lacks the real life situation of learning dance movement by a choreographer in a studio setting may affect the true representation of a dancer's movement span. It is therefore suggested that movement span capacities comparable to that of mnemonists may be observed through naturalistic observation of movement recall, such as, direct observation of dance sequence learning in a dance class setting with choreographers or dance instructors who are independent to memory research.

It was also noted by Smyth and Pendleton (1994) that there appear to be large differences between movement memory of dancers and non-dancers, but poor correlations between the number of trials required for recall and span performance in both dancers and non-dancers. Therefore, it is suggested that immediate span does not determine rate of learning. Furthermore, there may be better predictors of skill transfer, such as serial position recall. Starkes et al. (1987) investigated the interaction of choreographic structure of dance movement and performance in the recall of ballet movement of young expert and novice dancers. They found an interaction between skill level and structure for ballet recall. Serial position accuracy for verbal-recall tasks typically demonstrates primacy and recency effects (Murdoch, 1962); however, only primacy effects were demonstrated in the recall of ballet sequences (Starkes et al., 1987). No consistent differences between groups were observed for motor recall (physical demonstration of movement) versus verbal recall (verbally recalling a movement sequence) of choreographed movement.

Starkes et al. (1987) suggest the absence of recency effects may be due to the way in which dancers recall steps. Thus, regardless of recall type, participants utilised similar strategies for recall. In the structure of a choreographed routine it is not logical to report the last few elements, as is often done in verbal-free recall. Forgetting one item in a serial list appears to affect the remaining list items in contrast to a verbal memory task where participants can 'pass' and continue to report remaining items. In a second experiment, Starkes et al. investigated the effect of music cuing and primacy effects. It was found that although music enhanced recall, typical verbal memory serial position recall accuracy was not observed.

Deakin (1987) found similar primacy effects for expert and novice figure skaters in recalling free-skating elements. Therefore, the memory techniques employed by both

dancers and figure skaters does not seem to comply with typically observed results in verbal recall. Even though each dance or skate movement element has a name or label, dancers and figure skaters do not appear to perform on the basis of learned names. It can be argued that lack of a recency effect for recall of dance and skating sequences is due to output interference, such that the performance of early elements interferes with the storage of later items in short term memory (Deakin, 1987). If so, the mode of output-verbal or performance-should interact with serial position accuracy. Research (e.g., Deakin, 1987; Starkes et al., 1987) has demonstrated a difference in serial recall of movement patterns compared to standard serial recall task results; however, there is a lack of research of transfer between serial position tasks and motor tasks such as movement recall. If dancers are implicitly applying a rule of hierarchy for choreographed and nonsense movements perhaps, this mode of encoding and recall is generalised to all serial recall tasks.

In order to investigate whether strategies for processing movements are transferred to other measures of working memory, such as serial position tasks, we need to clarify whether a dancer's ability to recall long sequences of movement utilises the same sort of skilled memory observed in other areas of expertise (specifically, memory span for movements in dancers versus memory for chess pieces in chess masters). Despite the fact that movement spans of experts such as chess masters have not been examined in previous research, Allard and Starkes (1991) suggest that skilled movement memory is comparable to other forms of expertise, as it fits within the principles of skilled memory outlined by Ericsson and Polson (1988). Experts encode information using existing semantic-memory structures, as a large part of mastering these domains is learning the vocabulary.

Within working memory, verbal encoding is said to be the first stage in acquisition of expert skills (Anderson, 1983). It is argued that once language has been established, it is almost impossible not to utilise verbal labels, as everything is named, and thus, verbal labelling tends to take over (Damasio, 1999). Thus, an individual who has come late into dance may demonstrate different learning patterns to dancers who have started at a very early age; indeed, this may account for differences in effectiveness of encoding and recall ability amongst skilled dancers in learning patterns and memory ability due to the age of dance commencement. Although a late dancer may learn just as efficiently as the early starter, there may be clear differences in the patterns of learning related to general measures of memory span. However, when McKechnie (1984) compared the dance of children and adults, she noted the apparent lack of movement intelligence among adults who came late into dance. Consequently, she suggested that the children's kinaesthetic perception and knowledge precedes verbal coding, thus, contradicting Damasio's (1999) statement on the establishment of language acquisition impacting on skill acquisition.

Kinaesthetic perception appears to be a skill retained by those who dance. In other words, the practice of muscular movement overrides the knowledge of technical names and labels due to years of practice to develop muscular memory. However, there have been no studies to date investigating the differences in learning and memory strategies amongst motor skill experts such as dancers. While there is evidence to suggest that expertise impacts upon human memory and that dance expertise may influence our ability to recall movement, the research remains unclear as to the nature of this effect. For example, if, as the research suggests, expertise may provide a deeper understanding of the encoding strategies required to recall movement effectively, it is unclear how this would occur. The serial effect of movement recall may differ from the

normal serial recall of digits and letter strings. This may also be pronounced in those with extensive dance training (or individuals who have started at a young age) or, alternatively, different encoding strategies may be used altogether as a result of expertise, such that distinct differences may be made by comparing high and low memory span scores with movement learning patterns. This may be achieved by comparing movement memory recall over time with span tasks to identify whether there are correlations between measures of working memory.

The Current Investigation

As demonstrated by the preceding review of literature, there has been a surprising lack of investigation into whether general measures of working memory can predict learning and recall in areas of motor abilities such as dance. As such, the aim of the present study was to investigate whether working memory capacity is independent of the specific nature of the task at hand, and so represents a general resource for performing all cognitive tasks. This was investigated by analysing various measures of memory span (digits, letters different, letters similar, short words, long words, operation span) and a serial position task, then comparing results to the ability of expert dancers to recall classical ballet movement sequences. Although previous studies have examined the specificity and generalisability of expertise, there is a lack of research into what distinguishes effects from ineffective learners within a particular domain of expertise. Therefore, the current research also examined whether standard measures of memory can ultimately predict dance learning and rate of learning. Specifically, it aimed to investigate whether standard measures of working memory predict dance-learning patterns and, furthermore, whether some measures predict learning better than others.

It was hypothesised that a positive correlation would be demonstrated between memory span measures and dance recall due to similarities of working memory

components and elements of movement recall. Specifically, if correlations are found this may provide evidence to suggest verbal memory span measures are related to the recall of dance movement and thus, may involve superior memory components such as the rehearsal component of the phonological loop. Such a result would indicate that, although dance involves elements that are spatial, musical, visual and linguistic information, effective subvocal rehearsal may be instrumental in effective dance learning. Furthermore, it was hypothesised that serial position accuracy of dance items would reflect a descending serial position effect (i.e., a primacy effect but no recency effect) in contrast to the standard serial position curve (i.e., both primacy and recency effects) observed in general serial position tasks due to the nature of dance recall.

Method

Participants

Participants consisted of dance students studying at the Western Australian Academy of Performing Arts (WAAPA) in the Diploma and Bachelor of Arts programs aged 18 years and over. Recruitment involved an information letter, consent form and a participant expression of interest form (Appendix A, B & C), which was passed around to the students following an introduction meeting during the students' weekly Friday meeting. The sample size was 30 participants. Table 1 summarises the participant characteristics.

Table 1.   *Participant Characteristics*

Characteristics	*M*	Total Participants
Mean Age	19.23	
Mean Age Commenced Dance	5.43	
Female		23
Male		7
Bachelor of Arts Students		18
Advanced Diploma Students		12
1st Year Students		15
2nd Year Students		9
3rd Year Students		6

Design

In this study, the dancers were observed in their normal dance classes of Classical Ballet, learning and practicing new dance routines. There were three observational periods (dance class 1 to 3). In dance class 1, dancers were observed learning a new routine, whereas in dance classes 2 and 3, they were observed learning both new routines and recalling old routines (i.e., routines learned in previous classes). The two conditions were analysed separately; immediate recall of just learned movement (new) and recall of previously learned movement (old).

Dance movements were classified as elements. Thus, one movement equalled one dance element. Movement recall was calculated by tallying the correct recall of dance elements over five categories; correct footwork, arm position, head position, direction and timing. Each of these categories obtained a score of correct (2), partially correct (1) or incorrect (0). Each element then had a total of 10 possible points. Each movement item score was then tallied and averaged to give a percentage of correct recall for the total movement sequence. Scores across elements were then tallied to obtain a percentage of correct recall for the dance recall condition (new or old) over weeks 1-3. The movement sequences ranged from 10 elements to 18 elements depending on the class. An additional measure of dance element recall, was correct recall of the last two movement items in the dance sequence in both immediate recall (new) and previously learned recall (old). The scores reflected a total out of 10 possible points for each of the last two movement items using the previous rating scale.

Measures of memory capacity were undertaken in a series of computer tasks from the CogLab suite of programs (Francis, Neath & VanHorn, 2008). These measures were used to identify correlations between general memory span measures and dance

learning ability. The first measure of memory span utilised the Memory Span experiment. This measured memory span by presenting 5 types of stimuli: numbers, letters that sound different, similar sounding letters, short words, and long words. This task measured the maximum number of items that can be held in working memory (i.e., before items start to become forgotten). Thus, span scores represented the participants' span length for each of the stimuli. The second measure of working memory, the Operation Span task (Francis et al., 2008), measured memory span by presenting participants with a series of word stimuli to memorise while calculating a math problem. This test measured the ability to retain a sequence while working memory is at capacity, giving a total operation span score. This score was the sum of the sequence lengths that were recalled correctly. Memory for sequences was measured through the Serial Position experiment (Francis et al., 2008). A sequence of 10 letter stimuli was presented, and participants were then asked to recall the letters in the correct order. Serial position accuracy was calculated as a percentage of correct recall for each position in the sequence, resulting in 10 scores for each participant (e.g., serial position 1-10).

Materials

Materials consisted of a video camera for recording dance movements during rehearsal procedures. The students were observed learning new choreography for an assessment class in Classical Ballet. General measures of working memory required the use of the CogLab 2.0 program (Francis et al., 2008) utilising a computer running Microsoft Windows XP. The tasks included measures of memory span, operation span, and serial position. Participants' were also required to fill in a dance history questionnaire (see Appendix D) to identify further variables for analysis.

Procedure

Once participants were recruited, they were contacted via email or phone to arrange a time to take the CogLab computerised memory tasks. Appointments were made at convenient times for participants, either prior to the three-week observation stage, or during this stage. Depending on the participants' schedule they were given the opportunity to take all four cognitive tasks in one session or break it into two separate meetings. The memory span testing took a total of approximately 60 minutes.

Students were first required to complete the dance history questionnaire, followed by the memory span tasks. The first measure of memory span, the Memory Span experiment from CogLab (Francis et al., 2008) presented a sequence of items on the left hand side of the computer screen that were presented for one second. After the full sequence was presented, participants were asked to click on the buttons on the right hand side of the screen that were labelled with corresponding item names just presented in the same order. Once task was completed, participants were required to click on *Next Trial* to start the next sequence. Each of the five stimulus types, were presented five times with varying list lengths. Feedback was given on the participant's response to the previous sequence (correct/incorrect) before the next sequence was presented.

The next measure of memory span the Operation Span presented participants with a math problem, they were then asked to read the problem out loud and determine whether the given answer was correct or incorrect. If the problem was correct participants clicked on the *yes* button, if the problem was incorrect participants clicked on the *no* button. A word was then presented which participants were asked to read out loud. This process was repeated until participants were asked to recall all words that had been presented by clicking on the button labelled with the corresponding words presented in the correct order.

In the Serial Position experiment, participants were presented with a sequence of ten letters each presented for one second on the left hand side of the computer screen. Participants were then asked to click on the buttons on the right hand side of the screen that correspond to the letters shown in the sequence in correct order. The experiment included 15 sequences with different letters making up each trial. On completion of each cognitive task participants' scores were recorded by hand by the experimenter on a cognitive task tally sheet (Appendix E).

In the dance experiment, participants were filmed during their assessment class for approximately 1.5 hours per class. During this time, the participants learned a Classical Ballet movement sequence. For week one, a movement sequence consisting of just learned dance elements was used to analyse performance of immediate recall. This sequence ranged from 10 to 18 movement elements that varied depending on the class being observed. For the following classes (2 & 3) students were asked to perform the previously learned movement (from previous classes), and performance was analysed for the accuracy of recall. Furthermore, in classes 2 and 3 participants also learned new movement sequences from which another series of movement elements (approximately 10- 18 movements) was analysed to record a new measure of immediate recall for that class. Recall was calculated using the aforementioned measures of correct dance recall.

Results

Experimenter Bias

To ensure that experimenter bias did not influence the calculation of dance recall scores, an independent samples *t* test was conducted to compare the recall scores recorded by the experimenter and the recall scores recorded by a dance teacher independent of the study. Two sets of scores of one participant from week one over 18-movement elements were compared. The *t* test was not significant, $t(34) = .110, p > .01$, two-tailed, for the experimenter's reported dance recall ($M = 8.67, SD = 1.57$) compared to the independent teacher's recorded dance recall ($M = 8.61, SD = 1.46$). This indicates that the criteria used to assess the accuracy of recall were sufficiently objective to avoid bias in the experiment's scoring.

Serial Position

In order to interpret the correlations of working memory span task performance and dance recall performance, serial position accuracy was assessed to determine whether the dancers' memory for verbal information is functioning within the 'typical' way. A one way repeated measures analysis of variance (ANOVA) was used to identify whether expert dancers serial position memory for verbal information on a serial position task (not involving recall of dance movements) is functioning in the same way that other individuals recall serially. Specifically, it was investigated whether the participants demonstrated the typical serial position task that has been observed in previous experiments (Murdoch, 1962). The ANOVA indicated that recall performance on the serial position task varied due to the serial position of digits, $F (9, 261) = 4.12, p < .0.01$, partial $n^2 = .12$. These results are consistent with the standard relationship that is observed in the serial position recall task. The serial position curve is presented in Figure1. This curve has the typical shape of curves found previously.
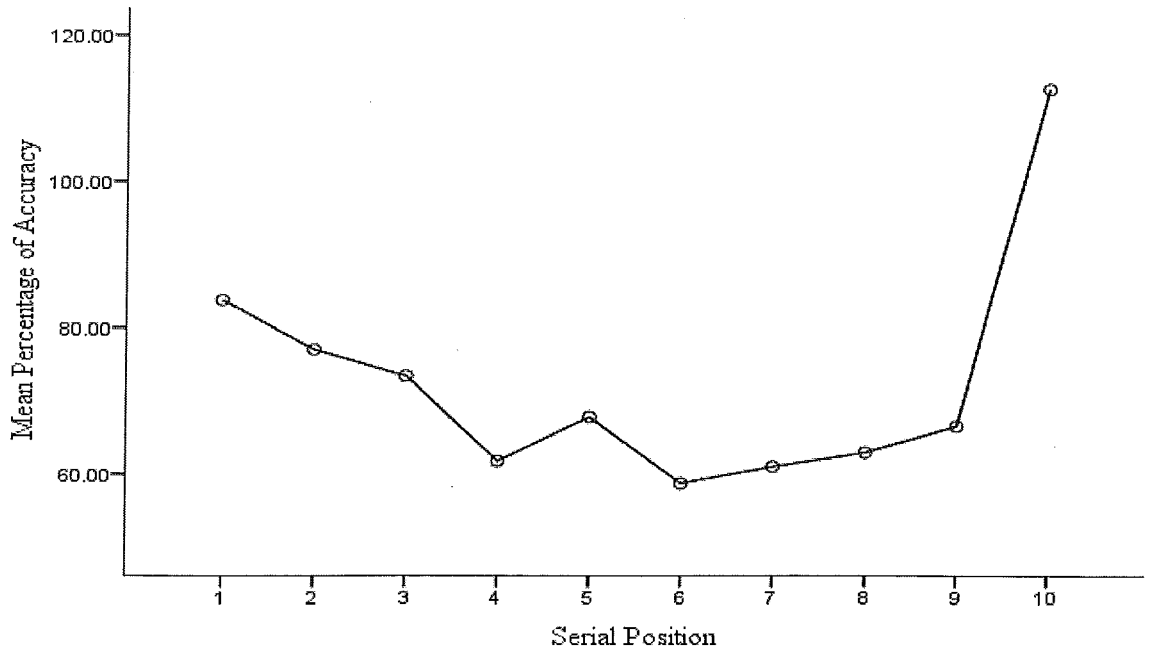
Figure 1.   Mean Percentage Accuracy as a Function of Serial Position

Memory span performance

　　　Average memory span performance was calculated for each of the working

memory span tasks to determine whether the dance participants demonstrated span

performance within the normal range. Table 2 provides descriptive statistics of the

dancers' performance on the memory span tasks, numbers, letters different, letters

similar, short words, long words and operation span.

Table 2. *Mean Performance of memory span tasks.*

Memory span task	M	SD
Numbers	6.57	1.22
Letters Different	6.27	1.08
Letters Similar	4.63	1
Short Words	4.47	1.13
Long Words	3.83	1.28
Operation Span	41.77	15.27

Dance recall and memory span

A series of bivariate Pearson's correlations were conducted to assess the linear relationship between dance learning and working memory span tasks to assess whether working memory span can predict dance learning. Prior to calculating r, the assumptions of normality and linearity were assessed, and the data was observed to be within acceptable limits. The Pearson's correlation was statistically non-significant ($p > .05$) between each of the working memory span tasks (digits, letters different, letters similar, short words, long words and operation span) and weeks 1-3 old (previously learned dance movement) and new (just learned dance movement) dance recall.

The serial position task indicated a statistically significant correlation between week 1 and serial position 2, $r(28)= .376, p < .0.05$, with 14.14 % of variance explained, and between week 1 and serial position 3, $r(28)= .435, p < .0.05$, with 18.92 % of variance explained. The correlation between week 2 old recall and serial position 4 was also significant, $r(28)= .365, p < .0.05$, with 13.32 % of variance explained.

Furthermore, correlations were found between week 3 new recall and serial position 3, r (28)= .433, $p < .0.05$, with 18.75 % of variance explained, and between week 3 new and serial position 5, r (28)= .385, $p < .0.05$, with 14.82 % of variance explained. Finally, the correlation between recall in week 3 old and serial position 1 was statistically significant, r (28)= .456, $p < .0.05$, with 20.79 % of variance explained and between week 3 old and serial position 3 was also significant, r (28)= .448, $p < .0.05$, with 21.86 % of variance explained.

Dance element recall and memory span

To assess possible correlations amongst working memory span and short-term working memory for dance elements, the last two movement elements of the dance sequences in weeks 1-3, old and new, were analysed separately. The association between scores and the memory span task scores was assessed with Pearson's correlation. The Pearson's correlation was statistically significant for week 1 element 1 and letters different r (28)= .393, $p < .0.05$, week 2 old element 1 and long words, r (28)= .484, $p < .0.01$, week 3 new element 1 and letters different r (28)= .423, $p < .0.05$, and week 3 new element 2 and letters different, r (28)= .535, $p < .0.01$. Significant correlations for serial position tasks and dance element recall are presented in Table 3.

Table 3. *Perason's Correlation for Serial Position Task and Dance Element Recall*

Variable 1	Variable 2	Correlation	P
Week 1 element 2	serial position 1	.422	< .0.05
Week 1 element 2	serial position 2	.545	< .0.05
Week 1 element 2	serial position 3	.545	< .0.01
Week 2 old element 1	serial position 2	.389	< .0.05
Week 2 old element 1	serial position 3	.555	< .0.01
Week 2 old element 1	serial position 5	.472	< .0.01
Week 2 new element 1	serial position 5	.419	< .0.05
Week 3 old element 1	serial position 1	.447	< .0.05
Week 3 new element 1	serial position 1	.422	< .0.05

Preferred Style and Dance Recall

Dance recall was analysed separately for the average recall performance of new dance elements across weeks 1-3 to assess the relationship between immediate recall and dancer characteristics. An independent samples *t* test was conducted to compare the average new recall of dance movement of participants who preferred ballet (n= 13) to the average new recall of dance movement of participants who preferred contemporary dance (n= 16). Neither Shapiro –Wilk statistic was significant, indicating that the assumption of normality was not violated. Levene's test was significant, thus, equal variances were not assumed. The test was statistically significant, with the participants who preferred ballet (*M*= 88.63 %, *SD*= 5.077) demonstrating higher percentage of recall than the participants who preferred contemporary (*M*= 82.84 %, *SD*= 8.92), *t*

$(24.48)= 2.19$, $p< .0.01$, two-tailed, $d= .46$. It is important to note that case seven was left out of this analysis because they preferred a third dance style which did not fit into the category of classical ballet or contemporary dance.

Discussion

The current study examined movement memory (recall of dance movement) and measures of general memory span and serial position. Firstly, the hypothesis was tested that there would be a positive correlation between memory span measures and dance recall, due to the similarities of working memory components and elements of movement recall. Specifically, it was hypothesised that if correlations were found this may indicate that verbal memory span measures are related to the recall of dance movement. Thus, the nature of memory components in dance such as the phonological loop may be enhanced due to subvocal rehearsal. Although dance involves elements that are spatial, musical visual and linguistic, effective subvocal rehearsal may indicate effective dance learning due to language like coding strategies of dance labelling (Stevens & McKechnie, 2005). Secondly, the effect of serial position on dance recall was hypothesised to demonstrate a serial position pattern that differs to the normal serial position curve (Murdoch, 1962), due to the logical serial nature of dance recall that has been identified by past research (e.g. Starkes et al., 1987).

Serial Position and Memory Span

Firstly, memory span measures (digits, letters different, letters similar, short words, long words and operation span) and serial position accuracy were explored to determine whether expert dancers' memory spans were functioning in the typical way found in previous research of ordinary individuals (excluding span performance found in mnemonists. e.g. Murdoch, 1962; Tulving & Patkau, 1962). This functioned to ensure that span measures are a meaningful comparison to dance recall. ANOVA testing revealed that collective recall performance on the serial position task, functions in the same way that past research has defined as the serial position curve (Murdoch, 1962). Specifically, recall performance varied due to the serial position. Recall was found to be

more accurate in the beginning and end positions of recall demonstrating both primacy and recency effects. Thus, serial positions in the middle of the sequence tend to be less accurate. Mean span task results also demonstrate that dancers performance is consistent with previous research indicating typical span of seven for digits and letters different, and a shorter span length for letters similar and long words (Tulving & Patkau, 1962).

Dance Recall and Memory Span

Firstly, the results obtained did not support the hypothesis that memory span performance would be positively correlated with dance movement recall, in terms of overall recall performance. Specifically, task performance of digits, letters different, letters similar, short words, long words, and operation span did not demonstrate a significant relationship with overall accuracy of dance recall during weeks one to three involving both previously learned dance movement (old) and immediately learned dance movement (new).

However, further inspection of movement elements did demonstrate a positive correlation with measures of memory span. Recall of the last two dance elements in a sequence, significantly correlated with performance on letters different and long words, for both new and old dance recall conditions. Therefore, the current results support the hypothesis that memory span would be positively correlated with dance movement, in terms of specific movement element recall. Correlations were found between; week 1 element 1 and letters different, week 2 old element 1 and long words, week 3 new element 1 and letters different, and week 3 new element 2 and letters different. Recall of the last two dance items of a movement sequence just learned (referred to as new, representing short term memory), were related to the span or recall of dissimilar letters. Conversely, recall of the last two dance items which have been previously learned

(referred to as old, suggesting long-term memory storage), are related to the retrieval of long words.

Secondly, the obtained results support the hypothesis that serial position recall of dance movement would differ to the serial position curve found in general serial tasks (Murdoch, 1962). The serial position task indicated significant correlations for both overall dance recall and for dance element recall. Significant correlations were found between; week 1 and serial 2, week 1 and serial 3, week 2 old and serial 4, week 3 new and serial 3, week 3 new and serial 5, week 3 old and serial 1, and week 3 old and serial 3. The serial positions that were serial positions 1 to 5, which reflect . stimuli that have been stored in long-term memory. Surprisingly, dance recall was found to be significant for both new and old movement conditions. Consequently, dance recall representing both long-term memory storage and short-term memory storage appears to be related to the long-term storage on general serial position tasks.

Furthermore, dance element recall and serial position task performance revealed significant correlations between; week 1 element 2 and serial 1, week 1 element 2 and serial 2, week 1 element 2 and serial 3, week 2 old element 1 and serial 2, week 2 element 1 and serial 3, week 2 old element 1 and serial 5, week 3, old element 1 and serial 1, and week 3 new element 1 and serial 1. It appears that short-term measures of dance recall (element 1 and 2) are related to long-term memory retrieval of serial position. This is consistent with the aforementioned correlations between overall dance recall and serial position performance. If the typical serial position curve was present in the serial recall of dance movement, significant correlations may be found between both the long-term measures of serial position (letter stimuli positions presented early in the sequence) and short-term measures (letter stimuli positions presented late in the sequence). However, as only long- term positions were found to be significantly

correlated with dance recall this suggests that serial dance recall does not function in a serial position curve found in general serial tasks (Murdoch, 1962).

Interpretation

The results demonstrated support of Conway et al's. (2005) theory of ability transfer and general ability, and Turner and Engle's (1989) theory of the general components of working memory capacity. Conversely, based on the significant correlations between memory span and dance element recall, it would appear that the results contradict research by de Groot (1966) and others (Daneman & Carpenter, 1980) that expertise is domain and situationally specific. Support of correlations between span measures (letters different and long words) and dance element recall suggests that working memory capacity is independent of the domain specific nature of a task, and hence represents a general resource that is used to perform all cognitive tasks.

As found in Turner and Engle's (1989) study, where they were able to successfully predict reading ability with a working memory span task that did not involve the reading of sentences, the current investigation provides support that verbal working memory span tasks may be able to predict something of the nature of memory for movement, specifically, the learning of dance movement. Although the current results did not predict the relationship between span capacity and movement span capacity, (as span performance is consistent with span results outside of expertise) it does provide support that there is a relationship between span performance and dance recall performance. Perhaps the demonstration of relatively normal span results in the memory span and serial position tasks reflect findings of Chase and Ericsson's (1981; 1982) case study of "SS" and "DD", the absence of ability transfer to word recall was concluded to be because of the absence of training strategies. Thus, average capacity limits applied. As the expert dancers demonstrated average span results, this may be due

to the absence of practice. Therefore, although a relationship was demonstrated between span tasks and dance element recall, transfer of memory abilities did not occur simply because of the absence of span task practice.

The current results suggest that due to the relationship between verbal span measures and movement recall, movement may be subvocalised regardless of the fact that dance movement involves motor processes and imitation of presented dance movement. Perhaps, this could be a result of established verbal schemas linked to the learning of dance vocabulary, that becomes innately programmed over years of dance learning (Stevens, & McKechnie, 2005). Therefore, reflecting a relationship between the capacity of the phonological loop and effective dance recall as a result of previous experience involving verbal encoding strategies.

Additional research has supported this idea of enhanced verbal rehearsal strategies in areas of musical expertise and span performance. For example, Chan et al. (1998) found higher verbal recall of words in expert musicians compared to novice musicians, in addition to Franklin et al. (2008) found superior reading span and operation span in musicians compared to nonmusicians. These results appear to suggest that musicians have memory expertise that extends outside the music domain and thus, reflecting general working memory components. However, both studies concluded that musicians possess an enhanced domain learned strategy involving verbal rehearsal mechanisms enhanced through domain-specific practice.

Furthermore, domain- specific practice allows individuals to utilise long-term memory as a means of extending short-term memory, through the creation of a domain-specific retrieval structures that enhance storage and maintain items in a more accessible, less interference-prone way (Tenenbaum, Tehan, Stewart & Christianen, 1999). The long-term working memory theory suggests that experts are able to encode

information quickly into a form that can be readily stored and, can be readily retrieved from long-term memory (Ericsson, 1985). Experts are able to use this superior knowledge base to set up retrieval structures (schemas). Ericsson and Polson, (1988) found that exceptional memory demonstrates evidence for explicit use of retrieval structures, as experts are able to set up cues that support rapid and efficient retrieval. The current findings support evidence for domain specific strategies as found by Ericsson and Polson involving explicit retrieval structures, (e.g., enhanced capacity of the phonological loop) through significant correlations found between verbal memory span performance and dance movement recall.

Preferred Style and Dance Recall

In addition to findings suggesting a relationship between memory span measures and dance recall, specific participant characteristics (outlined in the dance history questionnaire; see appendix C) were explored as a function of recall ability. Overall, recall performance of new dance sequences (weeks 1, 2 & 3 just learned dance movements) was compared between two groups of dancers; those who preferred contemporary dance and those who preferred classical ballet. A significant *t* test indicated that those who prefer classical ballet have a higher percentage of accuracy during weeks 1-3 new dance recall compared to those who preferred contemporary dance. These results are consistent with the current proposed theory of enhanced verbal recall structures due to the verbal choreographic nature of classical ballet compared to contemporary dance. Thus, individuals who prefer classical ballet may have an even more enhanced recall strategy involving the encoding of various dance steps into one single verbal chunk. Therefore, dance recall would be more accurate with efficient encoding strategies being put into place (Starkes et al., 1987). In other words, those who

prefer ballet may simply have more experience in verbal encoding and 'chunking' of ballet movements.

Additionally, classical ballet involves an established vocabulary of discrete named steps. Contemporary however, has no one single vocabulary. Choreographers are also suggested to develop their own movement lexicon that is comparable to non-verbal language, consisting of vocabularies of movement and a grammar comprising a system of structuring patterns of movement (Stevens & McKechnie, 2005). Dancers who express that they prefer contemporary dance over ballet may have more experience in contemporary dance and thus, have more experience involving an ever-changing movement lexicon. This may hinder one efficient verbal label for one movement, regardless of the readily available choreographic label of ballet steps being learned. In other words, contemporary dancers may not have as grounded acquired dance language that is readily available (Stevens & McKechnie, 2005).

Limitations of the Current Experiment and Directions for Future Research

It is important to note that there are some limitations to the current experiment to consider. Firstly, the current study was limited in terms of participant numbers due to time constraints, and of the participants recruited, there were a large number of first years that had only an estimated six months experience full time dance study. Although the dancers were considered experts due to the fact they attended a full time dance program that was restricted to obtaining a particular level of dance achievement prior to selection, some of these students may not have had as extensive dance training prior to admission into WAAPA. Thus, these dancers may not have developed the necessary learning strategies and recall abilities of someone with more experience. This may have impacted on the performance results in the dance recall conditions.

Furthermore, the goals and attained outcomes of the dance teacher who structured the dance class may also be an additional factor. It was not identified what each dance teacher was hoping to achieve in that dance class. A dance teacher may go into a dance class with the intention of improving the immediate recall, technique, or a combination of many other factors, thus, the teach will have based the class around these goals, which may inturn affect whether the dancer is focused on recall or improving technique. Both these factors may impact on the current results.

Lastly, the additional factor of dance injury was not taken into consideration. It is very rare to attend a class with all dancers being fit, well, and free of injuries. An injury may not take a dancer out of a dance class, however, it can impact on their ability to complete each movement successfully, cause likely distraction and effect concentration. It was not noted in the current study whether there were any existing injuries. There was no additional category for recall scoring of 'failure to execute movement because of injury'. It is unknown whether some execution errors represented by 0 or 1 in the current study, were in fact due to injury.

Although the results indicate that the nature of dance recall may involve the use of the phonological loop and subvocal rehearsal, how dance learning could be predicted remains unclear. Thus, future research could involve comparing a dancers span for verbal information on general span tasks and comparing this to movement span of verbal dance instruction and visual dance instruction (imitation). This may provide further evidence of subvocal rehearsal used in dance movement and may assist in enhancing dancers learning ability through early introduction of verbal labelling in learning a dance routine as a more effective and efficient form of encoding.

Future research could also involve not only memory for verbal contents (digits, letters, words etc.) but visuospatial elements too. Although the current results suggest a

relationship between verbal working memory and memory for dance movement, perhaps a further variable of visuospatial contents may confirm this assumption or suggest that better predictors of skill involve spatial components. Although past research such as Kane et al. (2004) found that verbal working memory span tasks (i.e. counting, operation and reading span) load on the same factor as working memory span tasks that involve spatial processing and storage in a factor analysis, research involving the aforementioned strategies may provide further evidence of Kane et al's. statement and provide additional support that working memory capacity is independent of the specific nature of a task, and hence represents a general resource that is used to perform all cognitive tasks.

In conclusion, the results suggest that although there is considerable evidence of general ability (Conway et al., 2005), general components of working memory capacity (Turner & Engle, 1989) and the possible link between enhanced subvocal rehearsal mechanisms in dancers. However, it remains unclear as to the nature of predicting dance learning using working memory capacity measures. Future research is required to identify confounds and variables that presently may impact on the true representation of results.

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Appendix A

Information Letter

HUMAN RESEARCH ETHICS COMMITTEE
For all queries, please contact:
Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170
Fax: 6304 2661
Email: research.ethics@ecu.edu.au

Thank you for your interest in this study. My name is Katrina Muller-Townsend. I am currently completing my Bachelor of Arts Honours in Psychology at Edith Cowan University.

The aim of the proposed research study is to investigate working memory in dancers. It is of interest how dancers memorise and learn new choreography and whether this relates to performance on general measures of working memory.
It is hoped that this research will provide further insight into the cognitive components of memory and learning.

Your involvement will require participation in four short cognitive memory tasks of approximately 1 hour in total. If you do wish to participate I will also be video recording your performance/ assessment class as you learn a new choreography piece. Your participation is totally voluntary and anonymous; if you feel you would like to withdraw from the study you are free to do so at any time without penalty.

If there are any queries or questions in relation to the present study, please do not hesitate to contact myself:

Email: klmuller@student.ecu.edu.au

If you wish to speak to my primary supervisor, Professor Craig Speelman on:
(08) 6304 5724
Email: c.speelman@ecu.edu.au

Alternately if you wish to speak to someone independent of the study please contact the Fourth Year Co-Coordinator Dr Justine Dandy
6304 5834
Email: j.dandy@ecu.edu.au
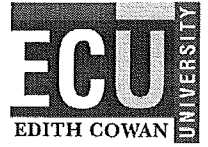
Thank you for your interest.

Regards
Katrina Muller-Townsend

Appendix B

Consent Form

HUMAN RESEARCH ETHICS COMMITTEE
For all queries, please contact:
Research Ethics Officer
Edith Cowan University
100 Joondalup Drive
JOONDALUP WA 6027
Phone: 6304 2170
Fax: 6304 2661
Email: research.ethics@ecu.edu.au

ECU
UNIVERSITY
EDITH COWAN

I _____ agree to participate in the 4th year Honours Research Study about Working Memory in Dancers, conducted by Katrina Muller-Townsend of Edith Cowan University.
I give written consent that:

- I have read the information letter and understand the purpose of the study.

- I have asked any questions or queries that I have about any part of the research, and have been answered sufficiently.

- I understand information that is disclosed will be confidential, and any identifying information will not be revealed without written permission.

- I will be voluntarily partaking in this study.

- I understand that information given will be only used in a research report given to official markers at Edith Cowan University. However, I accept that this report may be published under the provision that I am anonymous.

- I give consent to be video recorded during selected dance classes, and understand that these recordings will be destroyed after transcription.

- I understand that I may be re-contacted by the researcher if necessary, and I understand my right to request a preliminary copy if desired.

- I understand my right to withdraw from the project at any time, and any information already disclosed will be destroyed and removed from the research. I also understand there will be no penalty from withdrawing form the research project.

- I understand I can obtain a signed copy of this consent form if requested.

_____   _____
Participants Signature   Date

_____
Contact Number

_____   _____

Appendix C

Expression of Interest

Name	Course/Year	Phone Number	Email address	Availability Date/Time

Appendix D

Dance History Questionnaire

Name: Age:

Gender:

Course: Year:

Age commenced dancing:

Preferred Style of Dance:

Which describes your learning style or strategy for remembering choreography best:

Do you remember by (please circle one):

Labelling steps (naming)   Counting/ timing (beat values)

Naming steps with Sounds: Imagining the steps

Music/ rhythm

Other _____

Appendix E

Cognitive Task Tally Sheet

Name:

Date:

Time:

Memory Span:

Operation Span:

Serial Position:

Implicit Learning: