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# Unspoken Knowledge: Implicit Learning of Structured Human Dance Movement

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The sequencing of dance movements may be thought of as a grammar. We investigate implicit learning of regularities that govern sequences of unfamiliar, discrete dance movements. It was hypothesized that observers without prior experience with contemporary dance would be able to learn regularities that underpin structured human movement. Thirty-one adults were assigned to either an exposure or a control group. Exposure consisted of 22 grammatical 3-, 4-, and 5-movement sequences presented twice in random order; sequence duration ranged from 9 to 19 s. In a test phase, exposure and control groups identified previously unseen sequences as grammatical or ungrammatical, and rated confidence of judgment. The exposure group selected significantly more new grammatical sequences in the test phase than the control group. In addition, for the exposure group, the zero correlation criterion, wherein no relation between confidence and accuracy indicates unconscious knowledge, was satisfied. Through exposure, novice observers can learn a grammar that governs the sequencing of dance movements. This has implications for implicit learning of long sequences, working memory, and the development of expectations through exposure to contemporary dance.

*Keywords:* artificial grammar, human movement, observational learning, mere exposure, dance

Humans appear to have a remarkable capacity to learn the structural regularities of a particular language or musical environment through mere exposure and implicit learning (e.g., Dienes & Longuet-Higgins, 2004; Midford & Kirsner, 2005; Pothos, 2007; A. S. Reber, 1967; Saffran, 2001; Tillmann & McAdams, 2004). The range of this capacity is of interest here. We ask the following: Can implicit learning occur in response to relatively long, nonverbal patterns, such as movement sequences characteristic of contemporary dance? And does learning through mere exposure occur among observers with little or no prior experience with those types of movement patterns? The hypothesis under scrutiny is that through mere exposure, observers are able to learn regularities of an artificial grammar that underpins structured human movement. The aim is to test novice observers and their implicit learning of chaining of contemporary dance movements.

## Contemporary Dance and Its Relevance to Cognitive Psychology

In contemporary dance, the major medium is movement, deliberately and systematically cultivated for its own sake with the aim of achieving a work of art. Dance as an art form is relevant to cognitive psychology because it is a form of behavior that, since antiquity, has been found in all cultures. It is a sophisticated means of expression (Hanna, 1979), and communication through dance is intriguingly nonverbal, multimodal, and multidimensional (McCarthy et al., 2006; Stevens, Malloch, McKechnie, & Steven, 2003). Within the dance studio, dancers and choreographers often communicate with each other by showing complex phrases of movement rather than by using words (Grove, 2005). In performance, ideas are expressed through movement and stillness, rhythms, and sculpted patterns in space and time (Glass, 2006; Hanna, 2001; Stevens et al., 2003). The creation and performance of dance involves a complex interaction between procedural and declarative memory (Stevens & McKechnie, 2005).

## Vocabularies and Grammars of Dance

Unlike classical ballet, which refers to a repertoire or vocabulary of specific steps each with a descriptive French label, contemporary dance has no single repertoire of steps or sequencing of steps. A choreographer of contemporary dance (often together with a group of dancers) develops new movement material and chains that material in a particular way as the basis of a new work. Some

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sequences of movement may recur and be developed in the course of the work. Such sequences may be thought of as a grammar. Recognition of material as a work unfolds is a product of increasing familiarity on the part of the observer for movement material and/or particular sequences of, and relations between, movement material. Thus, an observer may develop specific expectancies for a particular dance piece as well as schematic expectancies for a particular style of dance or choreographic style or tradition. It is possible that this extends down to the sequence level with experts expecting a specific step after a given sequence of steps. These notions are comparable with the concepts of veridical and schematic expectancies as they develop in response to music—another temporal art (Bharucha, 1994; Meyer, 1956). We investigate the assumption that there is learning of movements that have been sequenced according to a structured system (or style) and use artificial grammar as the means to create these novel sequences.

## Implicit Learning, Temporal Sequences, and Human Movement

Learning is said to be implicit "when a person typically learns about the structure of a fairly complex stimulus environment, without necessarily intending to do so, and in such a way that the resulting knowledge is difficult to express" (Berry & Dienes, 1993, p. 2). Many fundamental human abilities—language, perception, motor skill, social behavior—reflect adaptation to the regularities of the world that evolves without intention to learn or awareness of what is known. One paradigm used to investigate implicit learning processes is artificial grammar learning wherein participants memorize a set of letter strings generated by a finite state grammar. They are then told that the strings followed the rules of a grammar and are asked to classify new strings as grammatical or not. Typically, participants perform this task better than chance would predict and are generally unable to describe the rules of the grammar (Bierman, Destrebecqz, & Cleeremans, 2005; Pothos, 2007). The artificial grammar paradigm differs from the serial response time paradigm in that the former includes a test phase wherein new, previously unseen grammatical sequences are introduced. These new stimuli test the generalization of exposure-phase acquired structure knowledge.

The use of human movement, specifically dance material, as stimuli affords new insights into implicit learning of artificial grammar structures. Initial investigations of the learning of artificial grammars were built on letters as stimuli (e.g., A. S. Reber, 1967). Material to be learned was visual, and the contents of a sequence of letters were presented simultaneously. Artificial grammar learning has been extended from simultaneous visual presentations to sequential presentations in the auditory modality, notably tone elements presented sequentially forming a grammatical sequence (e.g., Altmann, Dienes, & Goode, 1995; Bigand, Perruchet, & Boyer, 1998; Kuhn & Dienes, 2005). However, the duration of any one sequence is short. For example, Poulin-Charronnat, Tillmann, Perruchet, and Molin (2007) used 500-ms tones, which, when concatenated to form five- or six-tone sequences, were a maximum of 3 s in duration.

Dance material as stimuli provides an opportunity to investigate implicit learning of visual information with sequential presentation. Temporal unfolding occurs at two levels. There is presentation of movements to form a sequence as well as temporal and spatial information within each movement of the sequence. Short dance movements are used here, and overall sequence length is up to 19 s. Baldwin Andersson, Saffran, and Meyer (2008) explored statistical learning applied to human actions, but sequence length did not extend markedly beyond the durations of sequences used with tones, that is, 2 to 4 s.

The use of unfamiliar contemporary dance movements that extend in space and time and that are chained to form relatively long sequences has the potential to progress one of the current debates in implicit learning research. Notably, some experiments have investigated the influence of working memory and short-term memory, and particularly their limits, on the learning of grammatical sequences. Frensch and Miner (1994), for example, demonstrated that the rate of presentation of a serial response time task reliably affected learning as indexed by response times under incidental and intentional task instructions and under single and dual task conditions. Serial learning performance was better when the response–stimulus interval was 500 ms than when it was 1,500 ms. Thus, serial learning seems to be more likely for shorter stimuli, which are closer in time and have elements of a sequence that are simultaneously active in short-term memory. In addition, participants' short-term memory capacity (i.e., measured with memory spans) correlated with serial learning under dual-task conditions (see also Karpicke & Pisoni, 2004; P. J. Reber & Kotovsky, 1997). It remains to be seen whether serial learning takes place when movements and sequences extend significantly in space and time and when the movements involve whole body configurations (e.g., Smyth, Pearson, & Pendleton, 1988). The challenge for working memory in the implicit learning of long sequences may be gleaned from Unsworth and Engle (2005). In their experiment with high- and low-span participants, differences in learning as a function of working memory capacity emerged only in intentional but not incidental (implicit) learning in a serial response time task.

Searching for mechanisms that subserve action segmentation, Baldwin et al. (2008) examined the registration of statistical regularities in action sequences. The everyday, intentional motion elements (e.g., *pour, poke, clink*) would have been familiar to observers and extractable as segments. This differs from the present investigation in that our stimuli were unfamiliar dance movements sequenced in unconventional and unfamiliar ways. The dance movements had no specific label associated with them and were technically and aesthetically crafted.

Human movement is constrained by body morphology, forces of gravity, and dynamics of motion, and adult observers are sensitive to and can develop expectations pertaining to biological motion and anatomically possible human movement (e.g., Dittrich, Troscianko, Lea, & Morgan, 1996; Grossman, Blake, & Kim, 2004; Neri, Morrone, & Burr, 1998). Morphology and physics also influence choreography and dance. If a dancer leaps to the left, then the following phrase of movement will build, often (but not always), on the direction and momentum of that leftward leap. In the present experiment, momentum has been deliberately disrupted to show that an artificial grammar underlying movement can be learned during the course of an experiment and without the aid of existing implicit knowledge of body morphology and motion. This provides a more conservative test of the assumption that human movement that is sequenced systematically can be learned with exposure by novice observers.

Notably, there is movement, flow, and change within items but not across items; items are sequenced just as consonants and tones have been sequenced in previous studies according to an artificial grammar. Although long sequences could be created on the basis of flow and momentum (and thus also between items), precise control over existing grammars of biological motion would be lost, as would be control over demarcating the beginning and ending of movement of each item within a sequence. Finally, with continuously flowing material, it would be impossible to construct ungrammatical sequences without introducing new movement elements. Thus, the present experiment used phrases of bodily movement as items that were sequenced with precise experimental control according to the rules of an artificial grammar.

The present experiment has been designed with two broad aims: (a) to investigate implicit learning of new structures based on elements that are real-world material from an artistic and expressive context and (b) to use material based on body movements that extend in time and create relatively long sequences. An exposure group was presented with a series of movement sequences ordered according to an artificial grammar; a control group received no exposure. The dependent variable was accuracy in a subsequent test phase of identifying new sequences of movement that were grammatical (conformed to the original rule) or were ungrammatical (violated the rule). If artificial grammar learning extends to movement and to longer sequences, then the exposure group would be more accurate than the control group at selecting new grammatical patterns in a series of test trials. If learning is implicit, then there would be no relation between test phase confidence ratings and accuracy. This is the zero correlation criterion that is based on the within-subject relationship between confidence and accuracy (Dienes, 2004, 2008).

## Method

### Participants

Thirty-one Psychology 1 students at the University of Western Sydney participated for course credit. They were assigned randomly to either the exposure group (13 female and 2 male participants; $M = 21.6$ years, $SD = 4.47$) or the control group (13 female and 3 male participants; $M = 20.38$ years, $SD = 2.58$). Participants did not have experience with Australian contemporary dance, although some participants had training in other forms of dance, with means of 2.20 years ($SD = 4.85$) for the exposure group and 0.07 years ($SD = 0.25$) for the control group; the difference was not significant, $t(29) = -1.76$, $p = .09$. The median number of years of dance experience for both the exposure group and the control group was 0.

### Stimuli

The stimuli consisted of 66 sequences (22 grammatical exposure, 22 grammatical test, 22 nongrammatical test) of five different dance movements characteristic of mid-to-late 20th-century Australian contemporary dance style performed by an expert dancer. The movements from contemporary Australian repertoire can be described as *triple turn* (M1), *side fall* (M2), *body wave* (M3), *side kick and lunge* (M4), and *leg swing across floor front and back* (M5). Single frames from each of the M3 and M4 movements are shown in Figure 1. Duration of movements was 3–5 s, and duration of sequences was 9–19 s.

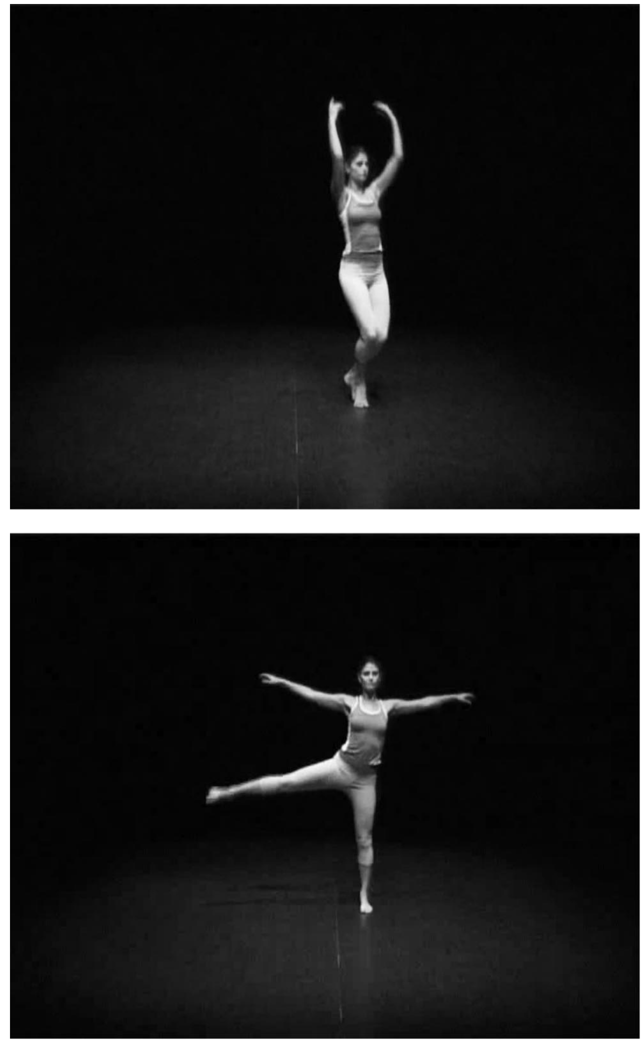

*Figure 1.* The single frames shown here have been extracted from Movement 3, body wave (upper pane), and Movement 4, side kick and lunge (lower pane). The duration of movements was 3–5 s, chained to form three-, four-, and five-movement sequences of 9–19 s duration.

Pilot studies directed the selection and production of stimuli. The five movements were chosen for the spatial differences in their start and end points (e.g., backstage right, center stage) serving to disrupt the natural bodily flow of the sequences between the items. This was done to eliminate memory for natural momentum that may draw on long-term knowledge of structured movement systems. Although discontinuous elements were necessary from a scientific standpoint, it also might have had an aesthetic impact, but the investigation of this impact is beyond the scope of the current work. The discrete movements were presented at the speed in which they were performed and spliced together with a very brief 24-ms fade-to-black transition between items. This imperceptible transition was used to eliminate a drastic change in screen redraw from one item to the next and to maximize the sequential nature of the stimuli.

The sequences were created according to a finite state grammar (Figure 2) that determines how each element of the grammar (i.e., one movement) can be combined into grammatical sequences. The

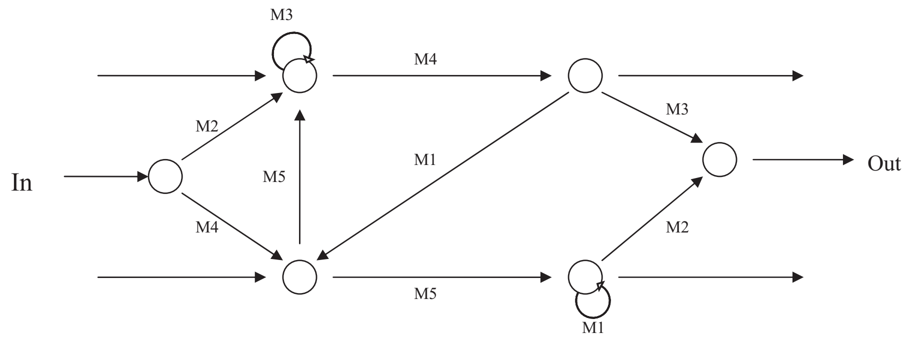


*Figure 2.* Artificial grammar, based on Poulin-Charronnat et al. (2007), used to construct three-, four-, and five-movement sequences. Each letter refers to a discrete contemporary dance movement (e.g., triple turn, side fall). The grammar generated 14 possible bigrams and 21 trigrams, all of which were used in the exposure phase and test phase grammatical and ungrammatical materials. M1–M5 = Movement 1–Movement 5.

ungrammatical sequences were constructed according to three constraints: (a) a movement in a grammatical sequence was replaced with one that also belonged to the set of movements; (b) this replacement created bigrams that also occurred in grammatical sequences; (c) the frequency distribution of movements and bigrams of movements was examined with the goal of closely matching the frequency distribution of grammatical sequences and ungrammatical sequences. For the ungrammatical test sequences, no new bigrams were created, but the replacement of a movement created 12 new (ungrammatical) trigrams.

Table 1 shows frequencies of occurrence for the 14 grammatical bigrams in exposure sequences, grammatical test sequences, and ungrammatical test sequences. The same transitions occurred in exposure and test sequences. Table 1 also shows that all bigrams from the exposure phase occurred in both test types with comparable average frequencies of occurrence. There were 14 possible bigrams, and our stimuli made use of all 14 in exposure, grammatical test, and ungrammatical test sequences. The average use of possible bigrams in the exposure phase was 4.93, and the average use in both the grammatical test and ungrammatical test sequences was 5.21. Because the average frequency of bigrams in grammatical and ungrammatical test sequences was the same, bigram learning could not lead to above chance performance. Participants would need knowledge about where in the sequence a bigram can grammatically occur (e.g., M1–M5 may occur legally in the middle of a sequence but not at the beginning of a sequence) and/or about higher level constructions, such as the grammaticality of trigrams (see later). Differences in frequencies of occurrence of bigrams in grammatical and ungrammatical sequences were distributed equally over bigrams and could not become an indicator of ungrammaticality.

Table 1
*Frequencies of Occurrence for the 14 Bigrams for Exposure Sequences, Grammatical Test Sequences, and Ungrammatical Test Sequences*

| Grammatical bigram | Exposure | Test: Grammatical | Test: Ungrammatical |
|---|---|---|---|
| M1–M1 | 1 | 4 | 6 |
| M1–M2 | 4 | 1 | 5 |
| M1–M5 | 9 | 13 | 9 |
| M2–M3 | 3 | 2 | 1 |
| M2–M4 | 2 | 2 | 5 |
| M3–M3 | 3 | 4 | 1 |
| M3–M4 | 11 | 9 | 9 |
| M4–M1 | 9 | 13 | 13 |
| M4–M3 | 5 | 3 | 5 |
| M4–M5 | 5 | 5 | 6 |
| M5–M1 | 6 | 7 | 5 |
| M5–M2 | 3 | 2 | 1 |
| M5–M3 | 4 | 3 | 3 |
| M5–M4 | 4 | 5 | 4 |
| *M* | 4.93 | 5.21 | 5.21 |

*Note.* M1–M5 = Movement 1–Movement 5.

Table 2 shows frequencies of occurrence for the 21 grammatical trigrams in exposure sequences, grammatical test sequences, and ungrammatical test sequences and reveals comparability of transitions occurring in exposure and test sequences. As shown in Table 2, among the 21 possible trigrams, the average use of possible trigrams in the exposure sequences was 2.24, in the grammatical test sequences it was 2.43, and in the ungrammatical test sequences it dropped to 1.24. These ungrammatical test sequences introduced 12 new trigrams, which were not grammatical.

Table 3 shows, for exposure, grammatical and test sequences, possible items in first and last positions, and whether the particular movements also occurred at other positions in the sequence. Table 3 reveals that four movements occurred in the first position and all five movements occurred in the last position, and that position of movements was well distributed across exposure and both test sequences. This analysis suggests that above chance performance in the test phase cannot be explained by anchor points or by the simple detection of new movements used in anchor positions.

The finite state grammar and the constraints that we described yielded 44 grammatical and 22 nongrammatical three-, four-, and five-item sequences of movements (see the Appendix). The five movements and sample sequences are available from http://marcs.uws.edu.au/?q=research/memory-complex-movement

## Equipment

A Sony digital video camera was used to record the dance stimuli in a professionally lit black box studio. Material was edited

Table 2
*Frequencies of Occurrence for the 21 Trigrams for Exposure Sequences, Grammatical Test Sequences, and Ungrammatical Test Sequences*

| Grammatical trigram | Exposure | Test: Grammatical | Test: Ungrammatical |
|---|---|---|---|
| M1–M1–M2 | 1 | 1 | 1 |
| M1–M5–M1 | 3 | 3 | 2 |
| M1–M5–M2 | 2 | 2 | 0 |
| M1–M5–M4 | 2 | 2 | 0 |
| M2–M3–M3 | 1 | 1 | 0 |
| M2–M3–M4 | 2 | 1 | 1 |
| M2–M4–M1 | 2 | 2 | 3 |
| M3–M3–M4 | 3 | 4 | 1 |
| M3–M4–M1 | 2 | 5 | 5 |
| M3–M4–M3 | 5 | 1 | 0 |
| M4–M1–M5 | 9 | 13 | 5 |
| M4–M5–M1 | 2 | 2 | 1 |
| M4–M5–M2 | 1 | 0 | 0 |
| M4–M5–M3 | 2 | 1 | 1 |
| M4–M5–M4 | 0 | 2 | 2 |
| M5–M1–M1 | 1 | 4 | 1 |
| M5–M1–M2 | 3 | 0 | 0 |
| M5–M3–M3 | 0 | 2 | 0 |
| M5–M3–M4 | 4 | 1 | 0 |
| M5–M4–M1 | 2 | 2 | 1 |
| M5–M4–M3 | 0 | 2 | 2 |
| *M* | 2.24 | 2.43 | 1.24 |

*Note.* For ungrammatical sequences, 12 ungrammatical trigrams were introduced: M1–M1–M1, M1–M1–M5, M1–M2–M4, M1–M5–M3, M2–M4–M3, M3–M4–M5, M4–M1–M1, M4–M1–M2, M4–M3–M4, M5–M1–M5, M5–M2–M4, M5–M4–M5. M1–M5 = Movement 1–Movement 5.

and sequenced for presentation with a Toshiba notebook and the video editing program, Ulead Video Studio 10.0. Stimuli were presented to participants with a Toshiba notebook.

## Procedure

Participants read an information sheet and signed a consent form as approved by the University of Western Sydney Human Research Ethics Committee. At the beginning of the experiment, participants in exposure and control groups were informed that the study was about perception of complex movement. At the end of the experiment, all participants were debriefed.

The exposure group was presented with 22 grammatical sequences, presented twice in random order. Participants were asked to look at each sequence and judge whether it had been seen previously during the experiment session. This memory task had the goal of making them watch the sequences attentively. A practice trial to familiarize participants with the task preceded commencement of the experimental trials; the practice trial used movements different from those used in the experiment trials. As a way of attracting attention to each sequence, a warning tone was sounded 1 s prior to the presentation of each sequence. There was an intertrial interval of 12 s during which a gray screen was displayed. To allow 10 min to pass between exposure and testing phases, participants were asked a series of questions regarding their dance experience and demographic information. The experimenter then described the artificial grammar paradigm, using English grammar as an example:

> The sequences were created according to a certain rule that determines how each step or phrase of movement will be combined into a sequence. There are certain combinations of steps allowed; the rule determines whether a sequence is legal or not. For example, in the English language, *a* can immediately follow *p* at the beginning of a word but *x* cannot immediately follow *p* if there are no vowels preceding *x*.

In the test phase, participants were presented with 44 previously unseen test sequences presented in 22 pairs: Each pair consisted of one grammatical sequence and the corresponding nongrammatical sequence separated by 1 s of blank blue screen. After having judged which sequence of a pair was grammatical, participants rated the confidence of their decision on a 5-point Likert scale (1 = *not confident at all*, 5 = *highly confident*). Confidence ratings were obtained on each trial. There was an intertrial interval of 7 s. Pairs always contained sequences with the closest match with respect to movements and transitional probabilities. Two different orders of the 22 test pairs were used across the sample. A practice trial with movements that were different from those presented in the exposure phase began the testing phase.

The control group completed the background questionnaire, watched the practice trial, and then completed the test phase. They received instructions identical to those given to the exposure group and followed the same procedure yielding accuracy scores and confidence ratings.

Table 3
*Patterns of Occurrence of Movements in First and Last Position (i.e., Anchor Points) in Exposure and Grammatical and Ungrammatical Test Sequences*

| Possible items in position: First position | Possible items in position: Last position | Any other position than first/last for grammatical sequences: Exposure | Any other position than first/last for grammatical sequences: Test | Any other position than first/last for ungrammatical sequences |
|---|---|---|---|---|
| | M1 | 2nd, 3rd, 4th | 2nd, 3rd, 4th | 2nd, 3rd, 4th |
| M2 | M2 | | | 2nd, 3rd |
| M3 | M3 | 2nd, 3rd | 2nd, 3rd, 4th | 2nd, 3rd, 4th |
| M4 | M4 | 2nd, 3rd, 4th | 2nd, 3rd, 4th | 2nd, 3rd, 4th |
| M5 | M5 | 2nd, 3rd, 4th | 2nd, 3rd, 4th | 2nd, 3rd, 4th |

*Note.* M1–M5 = Movement 1–Movement 5.

## Results

For the exposure group, performance on the memory task conducted during the exposure phase (i.e., answering whether a sequence had been seen on previous trials of the exposure phase) was above chance at 61.6%, $t(14) = 8.04$, $p < .0001$. In the test phase, as hypothesized, the exposure group selected significantly more new grammatical sequences than the control group ($M = 57.27\%$, $SD = 12.12\%$, and $M = 43.46\%$, $SD = 8.46\%$, respectively), $t(29) = 3.70$, $p = .001$. Performance of the exposure group was significantly greater than chance, $t(14) = 2.32$, $p = .036$, whereas performance of the control group was significantly less than chance, $t(15) = -3.09$, $p = .007$. A second control group of 15 participants (again with no experience of Australian contemporary dance) completed the experiment after being given instructions slightly different from those given to the exposure group. The second control group was asked to judge which of the two sequences was more flowing. They did not receive an explanation of the artificial grammar paradigm. The mean test score of this second control group was 48.18% ($SD = 11.62$), which was significantly different from the exposure group, $t(28) = -2.10$, $p = .04$, but not significantly different from chance, $t(14) = -0.61$, $p = .55$. There was no significant difference between test scores of the two control groups, $t(29) = -1.30$, $p = .21$.

Because all sequences were structured (even the ungrammatical sequences contained only one changed item), learning might have occurred during the test phase. For the first control group (i.e., the control group receiving the same instructions as the exposure group), we conducted additional analyses separating performance of the first and second half of the test phase. These analyses revealed that for the first control group in the first half of the test phase, performance was at chance ($M = .45$, $SD = .16$), $t(15) = -1.27$, $p = .22$, but in the second half of test trials, performance dropped below chance ($M = .42$, $SD = .15$), $t(15) = -2.18$, $p = .046$. For the control group, learning in the test phase might not necessarily have led participants to select the grammatical items. They might have expected more variability in sequences generated by a system and thus might have rejected these more regular sequences.

The most important result from analyses of the first and second halves of test phase performance is that the significantly better performance of the exposure group over the control group was not created by the below chance performance of the control group. In the first half, the control group performed at chance level, whereas the exposure group was both significantly greater than chance ($M = .61$, $SD = .15$), $t(14) = 2.90$, $p = .012$, and significantly greater than the control group $t(29) = 2.91$, $p = .007$. Thus, the effect of learning observed for the exposure group was not simply a function of the first control group's performance at the chance level.

As presented in Table 3, the material construction suggests that above chance performance in the exposure group cannot be explained by anchor points or by the simple detection of new movements used in anchor positions. However, the table also reveals that one movement (M2) was never used inside the sequence for the grammatical items, whereas this was the case for two (out of the 22) ungrammatical items. To check that the difference between control and exposure groups was not created by different response patterns to these two sequences, performance was analyzed for these items only: Exposure and control groups ($M = .46$, $SD = .51$, and $M = .47$, $SD = .51$, respectively) did not differ—a finding suggesting that above chance performance of the exposure group cannot be explained by this new placement of M2 inside the sequences.

The zero correlation criterion was examined with two methods (see Dienes, 2004, 2008). The first technique groups test scores with the lowest confidence rating (ratings of 1–2) to compute the average performance when guessing, and test scores associated with higher confidence ratings (3–5) are grouped together to give average performance when there is some confidence. If the performances associated with either high or low confidence ratings do not differ from each other, then the zero correlation criterion is satisfied. Participants without scores in the low-confidence range or without trials in the high-confidence range were excluded from the analysis, bringing the exposure group to $n = 12$ and the control group to $n = 14$. There was no significant difference between mean accuracy of low-confidence trials ($M = .60$, $SD = .21$) and high-confidence trials ($M = .54$, $SD = .16$) in the exposure group, $t(11) = 0.99$, $p = .34$, and no significant difference between mean accuracy of low-confidence trials ($M = .41$, $SD = .26$) and high-confidence trials ($M = .47$, $SD = .21$) in the control group, $t(13) = -0.66$, $p = .52$. The second technique separates correct and incorrect responses and calculates confidence ratings for these responses. In the exposure group, there was no significant difference between confidence ratings assigned to correct responses ($M = 2.75$, $SD = 0.81$) and incorrect responses ($M = 2.64$, $SD = 0.73$), $t(14) = 1.06$, $p = .31$. In the control group, there was no significant difference between confidence ratings assigned to correct responses ($M = 2.69$, $SD = 0.77$) and incorrect responses ($M = 2.55$, $SD = 0.84$), $t(15) = 1.14$, $p = .27$. The zero correlation criterion was thus satisfied according to both techniques.

## Discussion

This experiment has demonstrated that, through exposure, observers can learn regularities of an artificial grammar that governs the sequencing of contemporary dance movements. An exposure group performed significantly better than a control group and significantly better than chance in distinguishing previously unseen grammatical sequences from ungrammatical sequences. Because the zero correlation criterion was satisfied for the performance of the exposure group (on the basis of confidence ratings and grammaticality judgment accuracy), acquired knowledge may be represented at an implicit level.

The set of constraints used to generate ungrammatical sequences, such as replacing one movement in a sequence with a movement that also belonged to the set of movements and using ungrammatical changes that created bigrams that also occurred in grammatical sequences, enabled us to draw the conclusion that above chance performance indicates structural knowledge of the grammar above the bigram level and includes either position of bigrams and/or knowledge about possible trigrams. For example, equal average frequencies of occurrence of bigrams in grammatical and ungrammatical test sequences suggest that after exposure, participants had knowledge of where in a sequence a bigram can occur grammatically. Above chance performance of the exposure group is also not explicable by the occurrence of particular items in first and last positions or by the detection of new movements used in anchor positions. In contrast, above chance performance might be explained, at least partially, by the detection of new, ungrammatical trigrams.

Demonstration of implicit learning in the context of contemporary dance is significant for three reasons. First, implicit learning occurred in response to relatively long (19 s) stimulus sequences where the elements of the sequence also extended in time. The extended sequence length, although likely pushing the limits of working memory, did not defeat implicit learning. Unsworth and Engle (2005) reported effects of working memory span in intentional but not incidental learning conditions. The present results demonstrate the efficacy of implicit learning for the regular patterning underlying the order of movements in a sequence. Dynamic stimuli may facilitate such learning.

Second, even when momentum across items was disrupted, a demonstration of implicit learning for chained contemporary dance movements was realized. To destroy the flow of motion to which most adults would be attuned, the sequences were deliberately disrupted such that the end point of one movement did not flow into the starting point of the next movement. Effects may be stronger if momentum is maintained (although this would necessarily confound knowledge stored in long-term memory with the learning of new grammatical knowledge). Moreover, expert dancers who are keenly attuned to the laws of motion may return stronger results again where an artificial grammar across sequences of movement items builds on momentum and biological motion.

Third, it is significant for ways in which new audiences for dance might be attracted, retained, and developed that novice observers acquired knowledge of the underlying artificial grammar. This has practical implications for audience development. Repetition leads to the development of expectations. Such exposure builds perceptual fluency that becomes associated with a sense of familiarity and heightened preference for the movement material (R. Reber, Schwarz, & Winkielman, 2004; Szpunar, Schellenberg, & Pliner, 2004; Zajonc, 1968). Whether within a single work or across a body of dance works by a particular choreographer, familiarity, at least for novice dance observers, breeds content.

The creation and enjoyment of dance is more than the construction and recognition of an underlying grammar. In many instances of contemporary dance, the disruption of prior conventions is one goal. However, if there is a systematic set of relations governing the sequence of movements, then one way in which audiences may acquire knowledge of a particular dance, choreographer, or choreographic tradition is to acquire structural knowledge of relations. Just as expectancies develop through implicit learning in the domain of music (Tillmann, 2005), temporal, spatial, and kinesthetic expectancies can develop through implicit learning in the domain of contemporary dance.

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## Appendix

### Sequences of Movements Used in Exposure and Test Phases

| Grammatical | Ungrammatical |
|---|---|
| M2–M3–M3–M4 | M2–M4–M3–M4 |
| M2–M3–M3–M4–M3 | |
| M2–M3–M4 | |
| M2–M3–M4–M1–M5 | M2–M3–M4–M1–M1 |
| M2–M3–M4–M3 | |
| M2–M4–M1–M5 | M2–M4–M1–M2 |
| M2–M4–M1–M5–M1 | |
| M2–M4–M1–M5–M2 | |
| M2–M4–M1–M5–M4 | M2–M4–M1–M5–M3 |
| M3–M3–M4 | |
| M3–M3–M4–M1–M5 | M3–M3–M4–M1–M1 |
| M3–M3–M4–M3 | |
| M3–M4–M1–M5 | M3–M4–M1–M2 |
| M3–M4–M1–M5–M1 | |
| M3–M4–M1–M5–M2 | M3–M4–M1–M5–M3 |
| M3–M4–M1–M5–M4 | |
| M3–M4–M3 | M3–M4–M5 |
| M4–M1–M5 | |
| M4–M1–M5–M1 | M4–M1–M1–M1 |
| M4–M1–M5–M1–M1 | M4–M1–M5–M1–M5 |
| M4–M1–M5–M1–M2 | |
| M4–M1–M5–M2 | M4–M1–M1–M2 |
| M4–M1–M5–M4 | |
| M4–M1–M5–M4–M3 | M4–M1–M2–M4–M3 |
| M4–M5–M1 | M4–M5–M3 |
| M4–M5–M1–M1 | M4–M5–M1–M5 |
| M4–M5–M1–M1–M2 | |
| M4–M5–M1–M2 | |
| M4–M5–M2 | |
| M4–M5–M3–M3–M4 | M4–M5–M4–M3–M4 |
| M4–M5–M3–M4 | |
| M4–M5–M3–M4–M3 | |
| M4–M5–M4–M1–M5 | M4–M3–M4–M1–M5 |
| M4–M5–M4–M3 | M4–M5–M4–M5 |
| M5–M1–M1 | M5–M1–M5 |
| M5–M1–M1–M2 | M5–M4–M1–M2 |
| M5–M1–M2 | |
| M5–M3–M3–M4 | M5–M4–M3–M4 |
| M5–M3–M4 | |
| M5–M3–M4–M1–M5 | M5–M2–M4–M1–M5 |
| M5–M3–M4–M3 | |
| M5–M4–M1–M5 | |
| M5–M4–M1–M5–M1 | M5–M1–M1–M5–M1 |
| M5–M4–M1–M5–M2 | |

*Note.* M1–M5 = Movement 1–Movement 5.

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