The relationship between lapsing and scaling: Explaining timing variations in a contemporary dance performance

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Abstract
Timing variations in memory recall of a sequence of events are classified into two categories – lapses and scaling. Lapses refer to variations or errors made by inserting, deleting or mis-positioning material in a recall condition with respect to the serial location of the original material that was coded. This process is discussed in the context of a contemporary dance work performed with music and without music (here thought of as the recall condition). The two dance conditions were motion captured and compared. In addition to lapsing errors, it was hypothesized that a mechanism that produced time dilation of the encoded material was also present, producing a time scaling response (rather than lapses per se). This paper describes why it was purported in our earlier research that lapsing and scaling are not independent, and why they appear to merge at some points into what was referred to as ‘microscaling’. The present discussion argues that (1) there exists a mathematically conceptual transition between lapsing and scaling, making the two parts of a kind of continuum and (2) lapses are contingent on the identification of measurable conceptual or semantic units, making the physical units, of the kind that motion capture measures, an extension or special case of scaling. Motion capture divorced from an understanding of the semantic, syntactic and grammatical structure of, in this case, the dance work, cannot be used to identify lapses in a meaningful way. Future research wherein structural analysis of a dance work is compared with the lapse analysis developed here will determine the explanatory power and psychological validity of the concepts of lapsing and scaling in human memory for movement.

Keywords: Dance grammar; memory errors; structured temporal sequences; lapsing; scaling; timing; motion capture.

Preamble
This paper presents a discussion about the nature of timing variations made in recent studies of a contemporary dance work (Ferguson, Stevens, & Schubert, 2009; Stevens, Schubert, Wang, Kroos, & Halovic, 2009), and how the categorization of different types of timing variations or errors are constrained by the technologies used to measure and identify variation. The special case of temporal error is considered here through the examination of these recent studies that investigated a dance work performed in two conditions, once with music and once without music.

Memory Errors in Structured Temporal Sequences
When a temporal sequence, such as a list of words, a piece of music or a sequence of dance steps is remembered, the encoding, storage, or recall-production processes will not always allow production of the sequence to be accurately reproduced. This is because of various external influences (such as distractions) and memory limitations such as short-term memory capacity (Leff et al., 2009). The study of recall of previously remembered data focuses largely on natural language, in particular recalling lists of words (e.g. Kahana, Howard, & Polyn, 2008; Lewandowsky & Murdock, 1989) and memorization of music (e.g., Ginsborg, 2002; Williamson & Egner, 2004)). However, these studies can operate under the assumption that there exist discrete, meaningful units of information that can be remembered, forgotten or confused. In natural language this can be letters, phonemes, words, phrases, sentences and so forth. For music, it can be notes, bars, phrases and so forth. In such studies we assume that a fixed set of error types can occur, where a list of memorized words (for example) are recalled, and the location of the words in the serial order are monitored for their absence or presence, and—if present—how closely they are recalled to the original sequential location (for a review, see Kahana et al., 2008). The errors can thus be coded as deletions (a word from the original list is not recalled), an insertion (a word intrudes into the list) and a substitution (one word is swapped with another word in the list). It is also possible that an item can be moved so that it is recalled at the incorrect sequential location.
Discrete versus Continuous Error Segments

Such a ‘lapse’ analysis is effective when the data consist of discrete units. But what about situations where discrete units are not available or when physical signals have not been grouped into integrated, meaningful units or higher-order structures? For example, dance cognition researchers are only now starting to examine the possible grammatical structure of dance forms where a grammar was not previously availed to psychological study (Opacic, Stevens, & Tillmann, 2009). Under such circumstances we ask what are the units that can be compared for the purpose of memory recall?

Data Collection Method

This paper examines some of the questions related to the issues of timing variation and memory errors, and coding those errors, in the case of dance cognition, with reference to recently collected motion capture data. We have reported how dancers compare the production of a dance work under two conditions (Ferguson et al., 2009; Stevens et al., 2009) – the same choreography, but in one condition with music and in the other with no music, and ask the question that if the two are not performed identically (that is, using the same movement phrases in both conditions), what is the nature of the differences between the two renditions?

The dance work investigated in these studies was Reactional Movement, choreographed by Emma Batchelor and James Batchelor for performance in a program of works at the then Australian Choreographic Centre (now QL2 Centre for Youth Dance). The dancers had rehearsed the piece without music, and indeed some sections were performed without music, but the work had not been previously performed without music.

One of the three young dancer/choreographers wore a black lycra bodysuit onto which were sewn reflective markers. The dancer performed within a demarcated area, 5 m by 5.25 m. There were 24 reflective markers in all, including reflective tape attached to parts of the dancer’s body that were exposed. The left and right markers were placed on: ear (2), top and bottom of shoulder blade (4), top of shoulder (2), top of femur (2), elbow joint (2), wrist joint (2), hip joint (2), knee joint (2), ankle joint (2), foot (2); collar bone and base of sternum served as two reference points.

Analytic Approach

We did not code the performance movements into discrete syntactic, grammatical units, but rather examined the low-level, physical positions of the dancer from moment to moment. We wanted to determine whether the two renditions (with music and without music) were in the same sequence, but the measurement was more complex than identifying if a ‘dance step’ was inserted, deleted or positioned out-of-sequence. Instead, we examined the position of various parts of the body in time and compared those across the two conditions (with-music versus no-

music). This is analogous to comparing two speech signals using nothing but the acoustic data generated by the speech, rather than identifying the phonemes, words etc..

Consider the situation in speech recognition. A word needs to be identified from its acoustic components. So the system needs to recognize an expression such as ‘I need some help, please’. We could compare the speakers voice with a previous template recording (coding) of that same expression, but there are many complications that would make such a recognition system inoperable. The one of interest here is that the person speaking may, for some reason, happen to have exactly the same prosody, pitch and relative rhythm in production as the template recording, but the match fails simply because the speaker said the expression faster than the prerecorded template. This kind of ‘error’ – speeded up/slowed down—is different to the kind of lapse error that was identified above (insertion, deletion, substitution). We referred to this as a scaling error, and rather than lapses of segments or sections of the material to be memorised, this kind of tempo variation suggests that there exists an internal, time-keeping (Palmer, 1997) clock that plays the stored material back at the wrong speed – perhaps a little too quickly or a little too slowly.

In the dance scenario we were interested in both categories of errors: lapsing and scaling. To summarise, we have proposed two mechanisms that might explain how these different categories of errors occur: lapsing errors indicate problems due to recall of material in the wrong location (Palmer, Junters, & Jusczyk, 2001; Palmer & Pfardresher, 2003; Pfardresher & Palmer, 2002); scaling errors indicate that an internal clock has been miscalibrated at recall producing recall that was not at the original speed (Fu, Lau, & Wong, 2008; Hetland, 2004; Treisman, Faulkner, Naish, & Brogan, 1990). However after analyses of the data, the categories, as it turned out, did not produce a neatly defined dichotomy. While sections of the dance performance pairs could clearly be compared and identified as differing due to lapsing, and others due to scaling, some cases did not fit into one category or another.

Conceptual Region between Lapsing and Scaling Error Categories: Microscaling

In reporting the lapsing and scaling statistics of the study comparing a dance work performed once with music and again without music (Stevens et al., 2009), the authors concluded that the majority of errors in timing were due to lapses (deletions or insertions of material) compared to scaling. However, they did point out that apparent lapsing episodes could be identified over such short periods of time “that small consecutive lapses amount to miniature scaling episodes, or ‘microscaling.’” (p. 460). This raises two core questions when both lapsing and scaling are being identified using the same analytical process (i.e., comparison of temporal motion data):

1. How short can a lapse be before it is no longer a lapse?
2. Can consecutive lapses be chained together to produce the effect of scaling?

We propose here two approaches in dealing with these questions: one based on mathematical calculus, and the other on defining semantic units.

**Calculus**

Mathematically, the relationship between increasingly smaller units that straddle the categories of lapsing and scaling can be described by the principle of the limiting sum described in calculus (O'Brien, 1842/2005). By expressing a lapse as a collection of contiguous, short-time duration blocks, then again with the time-duration of each block made progressively smaller and smaller (while at the same time increasing the number of these blocks to fit the initial time span), it can be shown that a collection of infinitely small (in time) lapses become the equivalent of any arbitrary scaling. It is analogous to using a collection of small blocks (rectangles) to approximate the area under a curve. The curve is plotted to show the effect of scaling, but adjacent rectangular blocks are placed under the curve extending from the x-axis, each at heights that just touch the curve, placed horizontally and abutting until the width of the curve is covered, as shown in Figure 1. The sum of the area of the blocks is analogous to a 'lapse' interpretation of the timing disparities in the dance comparison (microscaling), whereas the smooth curve fitting over the top of the adjacent rectangular blocks provides an analogy to scaling. The thinner the blocks are made, and the more subsequent blocks satisfying the condition of extending from the x-axis until it touches the function, the closer the lapse becomes to fitting the function precisely. In other words, the lapses are merging to become the function area itself, scaling, as we find in integration calculus. This mathematical description demonstrates that lapsing and scaling categories can metamorphosise from one category to another, not unlike the transition between discrete and continuous time units of time scale calculus, as described by Agarwal et al (2002).

One problem with this calculus explanation is that it does not define at what point scaling and lapsing intersect or cross over – namely, when do lapses become so short that they could be considered scaling? This presents a practical problem of how to set thresholds when applying techniques to the problem such as moving cross correlation windows (Stevens et al., 2009; Wang, Schubert, Kroos, Chen, & Stevens, 2008), and dynamic time warping (Ferguson et al., 2009). Rather it suggests that the two categories are theoretically one — lapsing being an unrefined, coarse (in time) version of scaling. It does not take into account the (possibly arbitrary) conceptual distinction we have defined according to the different error category mechanisms. And while some theories, albeit controversial, have been posited about time quantum of duration experience ranging from 20 to 200 ms (Vroon, 1974) that may identify a psychologically plausible boundary, the calculus explanation provides only a theoretical account of the relationship between lapsing and scaling.

**Defining Semantic Units**

In language acquisition research, Luce and colleagues (Luce & Pisoni, 1998; Vitevitch & Luce, 1998) have described how sounds form phonemes and morphemes—the smallest meaningful language units—through replication and proximity. Word lists, of the kind mentioned at the opening, can be viewed as meaningful units (possibly though concatenation of morphemes, or single morphemes). It is the brains’ capacity to form meaning from these units and the underlying sequential structure that provide a springboard to the development and acquisition of language itself. Similar principles are found in music, where in Western music, for example, single notes are analogous to phonemes, and small groups of notes that regularly co-occur (Cooke, 1959; Narmour, 1990) are analogous to morphemes or, alternately, ‘musemes’ (Seeger, 1960), and so-forth. In dance, with the possible exception of some high
art forms such as ballet, and in particular in contemporary dance, there are less explicit physical and meaning units that are analogous to the phoneme and morpheme respectively. However, Opacic et al (Opacic et al., 2009) have demonstrated that the grammar, which is dependent on having those component units, can be learnt and abstracted from a dance work simply through mere exposure. They exposed participants to what could be thought of as dance phrases (which by analogy may themselves be thought of as combinations of gestures or ‘dancemes’, the smallest meaningful unit of dance, such as a step forward, a hand wave, a finger flick, and so forth), with five examples 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)” (p. 1572). These five movements were used as the basic structural components of their study of novice observers learning via mere exposure transitional probabilities (bigrams, trigrams) between movement units.

With a structural analysis of a dance, we are in a position to return the problem of applying the kinds of lapsing errors evident in memory for natural language, and we are able to instantiate the lapsing category of errors as the principle form of error analysis. It would allow us to bypass the complication imposed by identifying both lapsing and scaling categories of errors.

According to this argument, identification of insertions, deletions and substitutions of some kind of dance units is conditional upon having access to the grammatical or at least the ‘danceme’ level of movement. From this perspective, it may be premature to attempt the comparison of the same dance work under two conditions according to categories of lapsing and scaling errors. As our knowledge of dance structure and grammar emerges, we may start to move toward a position where lapsing errors can be based on perceptually relevant and meaningful units, rather than the physical positions of the dancers alone. Until that analysis is applied to the dance work, it may be more accurate to think of all lapsing errors as being extended microscaling.

**Conclusion**

This paper examined the fuzzy region between lapsing and scaling timing variations made in recent studies of a dancer performing in a-with-music and a-no-music condition of a choreographed piece with two other dancers. Without addressing this fuzzy, between-category region where an error is neither clearly a lapse nor scaling (or perhaps both, simultaneously) we have the pragmatic problem of how to select thresholds in algorithms designed to automatically identify lapse and scaling errors (Stevens et al., 2009). However, in this paper, we have addressed the question from a more philosophical perspective, and examined what the relationships between scaling and lapsing might be. The calculus account suggests that the two are a continuum, with lapses being at the coarse end of a memory error spectrum, and scaling at the limiting sum (infinitesimal) end. It is important to note here that although much of the literature we cite refers to ‘errors’, in the present dance cognition research we are more realistically interested in explaining why timing in one performance differs from another of the same choreography—this is not strictly due to error per se because error assumes that there is a correct ‘template’ version of a dance work against which a comparison is made. However, in the data that led to the current research questions, we were interested in the broader question of differences between two valid interpretations of the work (one with music and one without) rather than one ‘correct’ version against which the other would be compared. Such a distinction is required purely for analytic convenience, rather than reflecting psychological reality.

In conclusion, it may be possible to marry the calculus explanation of the distinction (or merging) between lapsing and scaling with the semantic unit explanation. As it stands, the studies that we have examined, that aim to code errors (timing variations) according to lapsing or scaling, should restrict themselves to scaling and microscaling until such time as meaningful units of motion in a particular dance style can be identified and coded for presence, absence or altered serial position across two performances of the same choreography.

**Acknowledgments**

This research was supported by the Australian Research Council through its Linkage Project and Infrastructure grant schemes (Grant Numbers: LP0211991, LP0562687, LE0347784, LE0668448), MARCS Auditory Laboratories at the University of Western Sydney, The University of New South Wales via its Strategic Investment in Research Scheme, and industry partners The Australia Council for the Arts Dance Board, The Australian Dance Council (Audsance), and QL2 Centre for Youth Dance (formerly the Australian Choreographic Centre). Our thanks to the team at QL2—Mark Gordon, Ruth Osborne, Gary Barnes, Quantum Leap Choreographic Youth Ensemble, Emma Batchelor, James Batchelor, Rebecca Frasca, and Sam Maxted. Further information: http://marcs.uws.edu.au.

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**Citation details for this article:**


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