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Temporal Awareness and Rhythmic Performance

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Temporal awareness (TA) can be defined as the awareness of the temporal unfolding of events, their temporal relationships (e.g., before, after, simultaneity) and the time intervals between them (Rantanen, 2007). Good TA allows for operators of dynamic systems to successfully diagnose the causes of the system's current state based on past events, and successfully predict possible future states based on that data. This definition presupposes that people possess a valid mental model of the systemic elements of their task, and is more in line with the notion of TA as an important component of situation awareness (e.g., Endsley, 1995; Rantanen, 2007; Sarter & Woods, 1991). Rhythmic performance will be defined here as behavior that arises in repetitive, wellpracticed tasks, and can be characterized as more or less automatic. This behavior always occurs along the temporal dimension and depends heavily on system components behaving in stable and predictable ways, which in turn facilitates the operators' understanding of such temporal patterns. Hence, rhythmic performance implies a well-developed temporal awareness of the system being controlled.

Real-world examples of rhythmic behavior abound; the mother who pushes her child on a swing in precise intervals while carrying on an animated conversation with a friend doing the same two swings over; the young athlete at the batting cages swatting baseballs at a constant clip while absorbing detailed technical instruction from his coach; and the drummer who sings lead vocals while maintaining a beat that all the members of the ensemble remain firmly entrained to. But consider also the many ways in which rhythmic actions can lead to overconfidence or complacency in one's tasks. One such instance was the mortar accident at the Rovajarvi shooting zone in 2005 (Accident Investigation Board, 2007). A seven-member mortar crew was attempting to fire nine mortar rounds in a 60s period. After confusion ensued between the leader, loader, and charger about how many rounds had been fired to that point, the 7th and 8th rounds were double-loaded, subsequently exploding in the mortar tube, and killing one and wounding several others. Of particular note in this scenario is the high skill-level of the crew and the highly regular intervals in which the actions occurred. The high skill-level of the crew allowed them to perform their tasks in an automatic, *feedforward* fashion, and the highly regular intervals in which the unit worked likely led to the acquisition of a strongly entrained rhythm, which the crew members were unable to break when faced with an anomaly (i.e., a round that was not fired) and stop their actions in time to prevent a disaster.

Automatic tasks are subject to specific error types that are quite different from those errors occurring in higher-level operating modes (Reason, 1990). Errors occurring in automatic or skill-based modes are deemed *slips*, and result from the failed execution of appropriate actions due to misplaced attention. While rhythmicity allows for highly accurate and easily sustained performance in regular task conditions, it may predispose people to slips when the conditions change in an unexpected manner.

The pros and cons of rhythmic control are well represented in a study by Grosjean and Terrier (1999), who found that subjects who developed a strong temporal awareness generally committed fewer control errors and used their rest periods more efficiently, but their performance on a low-level rote copying task suffered relative to participants who did not develop rhythmicity. Though the development of TA as defined by Grosjean and Terrier (1999) is a 'superior' strategy when it comes to avoiding errors in dynamic tasks, it would be lamentable if decisions based on knowledge of the temporal relationships between shifting elements was incapable of becoming streamlined into less resource-exhausting modes. It is instead likely that TA of dynamically and rapidly changing tasks must be mediated by a high-level, knowledge-based mode, and those tasks which present some stability, however subtle, can be mediated by rhythmic performance, or TA of a skill-based variety.

Acquired rhythmicity in performing a complex flow-line changeover in a simulated nuclear power plant (NPP) was demonstrated to be in many ways superior to performing the procedure according to protocol (Okada, 1992). Rather than maintaining in working memory the dynamically shifting information concerning water-levels, temperatures, and steam pressure, participants were able perceive a specific rhythm by which they could switch control lines that was at least as effective as the prescribed strategy. The repeated practice of on/off holding times facilitated the acquisition of a mental representation of the line changeover process, and subjects were able to perform even "unstable" condition tasks with minimal cognitive strain. Also, De Keyser (1995) has described one instance of a thermo-electric plant operator gaining knowledge of the system state by using temporally-sensitive markers that arise as by-products of normal plant functioning, but it is unclear whether these markers occur with enough regularity for a clear rhythm to be established. Evidence for perceived or acquired rhythm being dissociable from higher level cognitive functioning comes from more basic literature in a variety of domains.

The purpose of this research is to examine the advantages and disadvantages associated with rhythmic behavior, and attempt to establish the conditions within which people acquire rhythmic awareness in their tasks. Specific research questions include: (1) Can rhythmic behavior be characterized as skill-based and automatic, as opposed to controlled, attention-demanding, performance, (2) does rhythmic performance indeed reduce mental workload and attentional demands associated with the task, (3) what task characteristics allow for rhythmicity to develop, and (4) what sort of errors can we expect to occur in rhythmic performance?

A specially designed computer program that presents the subjects with four simultaneous tasks in a long sequence will be used to in an experiment to examine the above questions. The tasks must be completed within given time constraints ('windows of opportunity') and they will be sequenced in such a manner that that the subjects can perform them rhythmically, that is, in a regular pattern. Three rhythmic conditions will be examined: (1) simple rhythm, (2) complex rhythm and (3) dynamic or arhythmic condition. These timing conditions will be crossed with two levels of task difficulty, (1) easy, requiring only rote copying of a simple code to complete a task, and (2) difficult, requiring mental arithmetic to complete the task. The dependent measures will be the degree of rhythmiticity of the subjects' performance (measured by the variance in their attention to the separate tasks), time to develop rhythmic performance, and performance in completing the tasks.

We anticipate that there will be a significant interaction between the complexity of the pattern in task sequencing and task difficulty, so that those participants in the completely randomized (arrhythmic) conditions with the more difficult response task will experience enormous performance deficits and workload scores relative to those operators working in predictable environments with simpler response tasks. It is also expected that as rhythmic ambiguity increases, the length of time required for developing rhythmicity will increase; likewise with simpler rhythms and more difficult tasks. Perhaps the most important contribution of this work will be the development of a rhythmicity metric that can be applied to actual control environments in the field, such as NPPs, or military settings. Determining what conditions facilitate rhythmic entrainment "in the wild" will hopefully lead to a more complete understanding of why certain accidents occur in these environments, and how we might rein-in those errors that led to the Rovajarvi shooting zone mortar incident.

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