Using Audio to Train Pace in a Virtual Environment

Dr. Ali Ahmad, Northwestern State University of Louisiana

Ali Ahmad is the Head of the Engineering Technology Department at Northwestern State University of Louisiana. He received a B.Sc. degree in Industrial Engineering from the University of Jordan (Amman, Jordan; with Highest Distinction) and a M.Sc. and Ph.D. in Industrial Engineering from the University of Central Florida (Orlando, Fl, USA). He has diverse expertise in human-computer interaction, quality engineering, and simulating human-machine systems. He previously worked on projects related to transfer of training in advanced human-machine systems, usability evaluation of everyday products and services, and research in multimodal systems and virtual environments. His current research interests include virtual reality applications in manufacturing, multimodal interaction design, audio interfaces, advanced usability evaluation techniques, simulating complex human-machine systems, and advanced application of statistical techniques. Dr. Ahmad is a Certified Simulation Analyst and a Certified Six Sigma Black Belt.

Using Audio to Train Pace in a Virtual Environment

Abstract

Virtual reality has been used for training in multiple domains including military, healthcare and manufacturing. The integration of additional modalities (other than visual) is an ongoing research topic in virtual reality. This paper presents an experimental evaluation of the utility of using auditory cues to train temporal tasks (e.g., pace setting) in virtual training systems. There were four different auditory cues used for training pace: 1) a metronome, 2) non-spatial auditory earcons, 3) a spatialized auditory earcon, and 4) no audio. Sixty-eight people participated in the study. A pre- post between subjects' experimental design was used, with eight training trials. The measure used for assessing pace performance was the average deviation from a predetermined desired pace. The results demonstrated that a metronome was not effective in training participants to maintain a desired pace, while, spatial and non-spatial earcons were effective strategies for pace training. Moreover, an examination of post-training performance as compared to pre-training suggests some transfer of learning. Design guidelines were extracted for integrating auditory cues for pace training tasks in virtual environments.

Introduction

Auditory cues have been used to train spatial knowledge in virtual training systems from personal guidance systems for the visually impaired (Loomis et al., 1998) to Close Quarters Battle for Military Operations in Urban Terrain (CQB for MOUT; Jones et al., 2005). Nevertheless, there is an under explored opportunity for using auditory cues to present temporal information in such environments. This paper focuses on exploring the utility of auditory cues for training temporal tasks in virtual training systems. Temporal events or tasks are specific occurrences in time that can be either instantaneous (i.e., instant-based) or can span a time interval (i.e., interval-based) and often involve both (Schreiber, 1994).

Audio is known to be superior when compared to visual when processing such temporal information (ETSI, 2002; Kramer, 1994, Repp & Penel, 2002). When training temporal information, the appropriate training strategy will be dependent upon whether instant-based or interval-based temporal information is involved in the target training task. An example for using audio to train an instant-based temporal task is tapping a person's finger on a surface; the finger tapping can be controlled by playing a metronome sound that repeats every second, and asking the person to match their tapping speed with the metronome (Kurtz & Lee, 2003). Certain conditions, if met, enhance coordination accuracy and stability of such temporal performance, such as using synchronous and/or alternating tapping with fingers, and using simple harmonic ratios with pacing metronomes (Kurtz & Lee, 2003). In addition, motor learning can take place by extending perceptual learning (Meegan et al., 2000), which deals with performing tasks related to the use of the senses, such as discriminating temporal intervals denoted by brief auditory stimuli. This is beneficial to this work where pace training took place in a perceptual fashion, where participants acquired pace skills solely through a virtual training system without actual motor performance, and these would in turn need to be extended into motor learning when using the acquired pace skills in real world tasks.

The work to date on auditory pacing strategies has largely been done in the physical world. This paper explores the efficacy of using auditory information to guide participants in controlling their pace to a predetermined desired value in a virtual training system.

Background Literature

Real world applications for using audio to guide rhythmic movements are common in medicine, dancing, and sports (Boyle et al., 2002; Kaplan, 2002; Kern, et al., 1992; Libkuman et al., 2002; Wijnalda et al., 2005). When an external sensory stimulus is used to guide such rhythmic movement, audio cues generally result in the least variability from target rhythm as compared to visual or tactile cues (Kolers & Brewster, 1985; Chen et al., 2002). Once people synchronize their movements with that of auditory tones, they generally can maintain the pattern without the audio being played (Kolers & Brewester, 1985).

There are three types of temporally-related movements; these are goal-directed, rhythmic, and rhythm-modulated (Thaut, 2005). Goal-directed movements have a specific target, such as throwing a ball a certain distance in minimum time, or swinging a golf club. Rhythmic movements repeat at a constant rate such as tapping fingers or drawing circles. Rhythm-modulated movements repeat over time but at either increasing or decreasing rates, such as speeding up or slowing down during exercise. Audio can be used to influence all three-movement types. For goal directed movements, instant-based sounds can be used to time start and finish of a movement (Thaut, 2005). Rhythmic movements can be controlled using both instant and interval-based sounds. Instant-based sounds can be used to mark cycle ends for rhythmic movements (Thaut, 2005). Also, interval-based sounds can be used as a guide for rhythmic movements by providing sounds that repeat at a consistent pace. Controlling pace, or rhythmic movements in general, is contingent upon selecting an appropriate audio format for a specific time-related application. For example, an audio format that is often used to guide rhythmic movements is a metronome, which marks exact instant-based time increments by a regularly repeated tick (Kurtz & Lee, 2003). On the other hand, an example of interval-based audio is using sounds with varying tempos that indicate relative distance to objects (Day et al., 2004); i.e., shorter time delays between sounds as a user gets closer to a target or destination.

Rhythm-modulated movements can be controlled using interval-based sounds. In general, rhythm-modulation with audio cues involves using sounds that repeat at increasing or decreasing pace as a guide for physical movements. These movements are common in rehabilitation studies that involve gait, where typically a music tempo is initially chosen that accommodates an individual's gait capabilities and then the tempo is increased incrementally as gait performance improves (Thaut et al., 2004). Metronome use in behavioral ecology studies dates to the late 60's (Wiens et al., 1969); researchers have generally used metronomes to monitor specific individual's activities over time, or to time individual actions. For example, metronomes (or feedback earcons, i.e., auditory icons) have been used in training Cardiopulmonary Resuscitation (CPR; Kern et al., 1992; Boyle et al., 2002). Metronomes have also been used to train rhythm-driven arm movements. For example, Thaut (2005) used a metronome to synchronize movement frequency and found less spatial and temporal variability in metronome-driven trials as compared to self-paced trials. Thaut (2005) also used a metronome stimulus with three different sections (beats per minute) to demonstrate that participants were able to re-synchronize with a changing metronome within 50 ms. An interactive metronome, which plays feedback earcons, has been used to train consistent and correct timing on tasks (Bartscherer & Dole, 2005). For example, Libkuman et al. (2002) discuss an experiment where an interactive metronome was used for golf training. A constant metronome was played to guide participants in different tasks that they were required to perform (e.g., continuously moving hands in a circle and clapping them when they reached a particular point in the circle; a metronome was used to indicate at which point they should clap). In addition, earcons provided feedback regarding whether movements were late (low pitched tone in the left ear), early (high pitched tone in the right ear) or on time (+/- 15 ms of beat; high pitched tone presented in both ears at the same time). An experiment was performed in which pre and post evaluations of accuracy of golf shots from people who used this training device to train timing was compared to those who used other forms of golf training. Results suggested that training in timing and pacing of fine motor activities using audio as guidance can transfer to more complex tasks such as golf swings. This study is of interest since it shows that although the metronome-based training was not directly associated with the actual golf training, it still gave participants a grasp over pace control that was later useful when performing actual golf swings. There has been no use for spatialized feedback earcons or metronomes in pace setting to the best of the authors' knowledge.

Taken together, these studies demonstrate, as Kaplan (2002) suggested, that metronomes or interactive earcons can be used:
• To produce steady clicks to indicate desired beat.
• At the beginning of an exercise to establish the right tempo that corresponds to a beat and at the end to check whether the tempo stayed the same.
• To gradually become comfortable with a faster or slower tempo.
• To train consistent and correct timing on various tasks.

Design principles for conveying temporal information in virtual training environments can be theorized based on the above review; these include:
1. Metronomes can be used to train a consistent pace.
2. Earcons/metronomes can be used to gradually increase or decrease traversal pace.
3. Metronome-based (or audio-based in general) pace setting can be used to train paces that become internalized and can be used when a metronome is removed.

Method

This study utilized a virtual reality training system to perceptually train participants on a pace setting task. Each participant performed pre-training, post-training, and a set of eight training sessions. The training sessions included audio cues for training pace, as discussed below. Participants' performance was assessed by:
• Comparing performance on training session 8 (audio cues present) to pre-training to assess the utility of using audio to cue pace.
• Comparing performance on post-training (no audio cues present) to pre-training to assess pace internalization.

A total of sixty-eight participants (mean age = 19.9 years; s.d. = 3.6 years) participated in this study. Participants were randomly assigned to one of four different treatment conditions. All participants reported normal or corrected to normal vision and normal hearing. The virtual environment was designed to mimic a room clearing exercise and included a 15 room building to be cleared. Ten different variations of the environment at comparable task difficulty were created to be used for training and testing. Each environment contained 5 open doors, 8 enemy entities, 4 friendly entities, and 4 mouse holes (i.e., hole in the wall). Figure 1 shows an example environment layout.

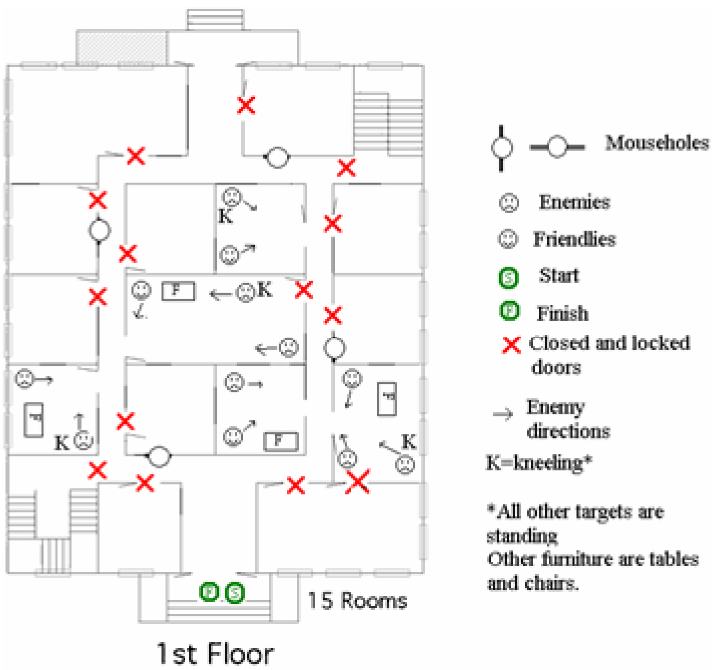

Figure 1. Virtual Environment Layout Example

Four different versions of each environment layout were created based on the various audio conditions evaluated (see experimental design, below). All environments had “user’s footsteps” and “gun shots” sounds implemented. One environment variation was randomly selected for pre and post-testing. The pre and post-testing environment didn’t include auditory cues for pace training. Pre and post-testing were used to assess the perceptual transfer of training within virtual environment task performance when auditory cues are removed. In addition, the training environments had audio implementations depending on the experimental condition;

• No audio: No audio cues for pace training were present, i.e., only “user’s footsteps” and “gun shots” sounds were implemented.

• Metronome: A metronome sound with three settings (slow: 2 m before open door; medium: no open door or mouse holes; fast: 2 m before and after mouse holes) was implemented depending on the location of the participant in the environment.

• Non-spatial earcons: Two diotic metaphoric audio cues were selected to guide participants in setting their pace. If the participant was traversing the hallway at the “correct” pace, no audio was played. If the participant needed to slow down, a drum sound was played. If the participant needed to speed up, a flute sound was played. The rate of the played audio was proportional to the deviation from the predetermined desired pace.

• Spatialized earcons: A spatialized (front or back) metaphoric audio cue was selected (flute) to guide participant in setting their pace. If the participant was traversing the hallway at the “correct” pace, no audio was played. If the participant needed to slow down, the audio was played in front of the user. If the participant needed to speed up, the audio was played from the back. The rate of the played audio was proportional to the deviation from the predetermined desired pace.

Each participant performed a series of CQB for MOUT activities in a virtual environment. There were two primary tasks that the participants were expected to complete. The first task was to maintain a consistent pace while traversing the environment hallways. Three predetermined paces were selected based on the environment configuration and dimensions, these were a slow pace when approaching open doors, a fast pace when passing mouse holes on walls, and a medium pace when no open doors nor mouse holes were present. The second task was to enter and clear all open rooms and engage all hostile and non-hostile units located therein. To engage units, participants had to point their weapon towards a unit, and then use the correct button on the game controller to identify them as either friendly or foe (i.e., left controller button was used to clear friendly units, and right controller button was used to fire upon foe units). When moving through the environment, turning was controlled through head movement. Locomotion (i.e., stepping forward and back) was controlled using the game controller.

This study utilized a pre-post between subjects one-factor ANOVA design. The one factor was audio condition, with four different levels: 1) a metronome, 2) cueing using non-spatial audio (using one audio cue to indicate the need to speed up and another audio cue to indicate the need to slow down), 3) cueing using 3D audio (audio was played either in front [to push them backward] or to the back [to push them forward] of the listener to regulate pace); and 4) a no audio control. Performance was assessed using the average deviation from the predetermined desired traversal pace for the hallway traversal task, and time and accuracy for the room clearing task. Both audio cueing effects on pace setting (comparing last training to the pretest) and near term transfer of pace setting skills (comparing post-test to the pre-test) were evaluated. Performance on the room-clearing task was assessed using percent hits over fire and average task completion time. In addition, workload, presence, and simulator sickness were assessed, but the analysis of their data is included in another manuscript under preparation.

Before the start of a test session, participants completed an informed consent and demographics questionnaire. After that, participants completed task training involving interaction with the training environment and a pre-recorded animation that illustrated the predetermined traversal paces. Once the training was done, participants completed a pre-test, where they were required to complete their tasks with no audio cueing. Then, participants were randomly assigned to one of the four different audio conditions. Additional training was given based on the assigned condition. Participants in an audio condition watched a presentation illustrating the earcons that they would experience, while participants in the no-audio condition were reminded verbally on their task objectives and the need for maintaining a consistent pace. Participants then completed eight training sessions based on the assigned experimental condition. The order of the training sessions was randomized for each participant. After the training sessions, participants completed a post-test, which used the same environment and settings as the pre-test. Finally, the participants were provided with a written and oral debrief about the pace training experiment.

Results

Performance data in terms of participants' location, speed, and time were logged through the experimentation software. Although 68 participants completed the study, only 53 had their data correctly logged via software, and hence were included in performance data analysis. Participant log files were processed for average traversal paces and average deviations from predetermined desired pace. Statistical significance was assessed using an alpha of 0.05 for pace performance, which may have induced some variation. Table 1 provides means and standard deviations on average traversal pace, average deviation from predetermined desired pace, percent hits over fire and average time to complete each task for pre-training, training session number 8, and post-training. These results included performance on both pace and room clearing tasks. Nevertheless, since the objective of this study was pace training, more attention will be given to pace task performance.

Table 1. Descriptive Statistics for Pace Performance

Dependent Variable	**Audio Condition**	**Pre Training**	**Training 8**	**Post Training**
Average Pace (Hall, Mouse Hole, and Door Entry).	**No Audio**	0.3810 (0.0925)	0.4310 (0.0942)	0.4334 (0.0866)
	Metronome	0.3751 (0.0928)	0.4426 (0.0939)	0.4077 (0.0989)
	Non-spatial	0.3975 (0.0880)	0.3946 (0.0521)	0.3615 (0.0935)
	Spatial	0.3668 (0.1037)	0.3784 (0.0719)	0.3450 (0.0539)
Average Deviation from Desired Pace	**No Audio**	0.11438 (0.03565)	0.1254 (0.0576)	0.1093 (0.0621)
	Metronome	0.1171 (0.0417)	0.1228 (0.0591)	0.1110 (0.0612)
	Non-spatial	0.1290 (0.0469)	0.1010 (0.0455)	0.1193 (0.0494)
	Spatial	0.1065 (0.0380)	0.0894 (0.045)	0.09418 (0.03343)

Table 2 presents ANOVA p-values for average pace and average deviation from predetermined desired pace for entry danger areas, mouse hole danger areas, and hall traversal. An ANOVA was used to compare the average deviations from the predetermined desired pace among the various audio conditions. ANOVA results show significance for both training session number 8 compared to pre-training ($p < .002$) and post-training compared to pre-training ($p < .06$). Tukey's post-hoc analysis indicated that the average deviation from predetermined desired pace for the no audio condition was significantly different from the non-spatial auditory cueing condition ($p<.004$) and the spatial auditory cueing condition ($p<.021$). On average, the deviation from predetermined desired pace for the no audio condition was greater than that for the non-spatial audio by 0.05534 m/s (s.d. = 0.01526) and greater than that for the spatial audio by 0.04587 m/s (s.d.= 0.01526). These results suggest that spatial and non-spatial audio appear to be more effective strategies for pace setting for hall traversal and in the vicinity of mouse holes than no audio. Also, the graphs indicate that the metronome was not an effective strategy for pace setting. The average deviation from predetermined desired pace for the metronome cueing condition was 0.01404 m/s (s.d. = 0.01464) greater than that for the no audio condition, which was not significant ($p>.770$).

Table 2. ANOVA Comparisons

Dependent Variable	**Training 8 – Pre-training**	**Post-training – Pre-training**
Average Pace (Door Entry)	0.426	0.561
Average Pace (Mouse Hole)	0.117	0.001*
Average Pace (Hall)	0.452	0.206
Average Dev (Door Entry)	0.291	0.522
Average Dev (Mouse Hole)	0.962	0.020*
Average Dev (Hall)	0.002*	0.055

* Significant

Discussion and Conclusions

The present study examined the utility of using audio to train pace in an interactive virtual training system for MOUT CQB. In particular, three auditory conditions were compared to a no audio control group to assess the utility of using auditory cues to set pace and whether short term transfer of training for pace skill can take place.

The results of the experiment revealed that using a metronome was not effective in training participants to maintain a desired pace. This is at odds with past literature that suggests metronomes can be used for guiding rhythmic movements in the real world (c.f., Kern, et al., 1992; Boyle, et al., 2002, Kurtz & Lee, 2003). Thus, there may be a fundamental difference between physical and virtual worlds that hinders the use of a metronome. This might be due to the difficulties of metronome implementation with respect to footstep sound implementation. When trained with the metronome, participants had to match two sounds; the footsteps sound to the metronome, which may have been difficult due to volume differences between the metronome and footstep sounds. Future virtual metronome implementation should consider the relationship between metronome loudness level and the other sounds present, such as footsteps, and consider training first with just one of the sounds (e.g., the metronome) and then introducing the sound that is to be synched to the metronome. Although in real world applications, a metronome is a very effective strategy for pacing setting, this study has shown that there might be some difficulties in integrating a metronome in interactive VE training systems. These findings fail to validate the first design principle that metronomes can be used to train a consistent pace in virtual environments.

On the other hand, the results of the present experiment provide preliminary validation for using earcons to influence (increase/decrease) traversal pace gradually. Specifically, auditory cueing, as indicated by deviation from predetermined desired pace for the difference between training session number 8 and pre-training, has shown to be an effective strategy for setting desired pace. Both the non-spatial and spatial audio conditions resulted in less deviation from the predetermined desired pace as compared to the no audio condition and these deviations were statistically significant. This supports the literature related to using auditory cues to drive pace setting (c.f. Karageorghis & Terry, 1997; Thaut, 2005).

The results also suggest that audio-based pace setting in virtual environments may become internalized and thus can be used when the audio is removed. Specifically, examining performance on post-training compared to pre-training, indicates that the average deviation from desired pace in hallways was significant when audio cueing was present (i.e., training session number 8, $p<.002$), as well as when it was taken away upon post-training (i.e., post-training, $p<.055$), suggesting transfer of learning, or the ability of participants to maintain pace setting when the audio cueing was removed. This extends the literature describing the internalization of pace skills. Past literature demonstrated that people maintain their rhythm after removing a synchronizing auditory cue, and when people learn timing on fine motor tasks (like drawing circles or clapping hands) using metronomes and feedback earcons, the learned skills transfer to more complex skills, such as golf swings (c.f. Kolers & Brewester, 1985; Libkuman et al., 2002). Previous research dealt with training pace using auditory cues in the real world, whereas in this study, the pace training findings are extended to a virtual world and show that internalization is attainable in virtual environment training systems. The evidence supporting internalization is very encouraging, as it suggests that virtual environments may be effective trainers for temporal skills that may be difficult to train in the real world due to limited access or potential danger (e.g., emergency procedures, military operations, etc.).

An interesting finding from this study was that both non-spatial and spatial auditory cueing resulted in comparable pace setting performance. The non-spatial audio condition used two different earcons, while the spatial audio condition used a front-back spatialization of a single earcon. Both audio conditions had a similar implementation of earcons' variation based on deviation from desired pace, where the rate of played audio was proportional to the deviation from the predetermined desired pace. The implication of this finding could be that if auditory earcons are to be used for pace training in a virtual environment, the choice of implementing spatialized or non-spatialized earcons can be a design decision, as both appear effective. If the environment contains many spatialized cues, then using non-spatialized cues might be a better option. Nevertheless, if there are several different earcons in the environment, spatialized earcons could be a better option, as they can simplify the number of earcons used.

The results of the study presented in this paper provide design principles for integrating auditory cues in interactive environments to train temporal tasks (e.g., setting pace), these include:

- Spatialized and non-spatialized auditory earcons may be effective strategies for pace training in interactive training systems.
- Audio designers should consider using spatialized earcons when there are several different earcons in an environment (adds one less earcon).

• Audio designers should consider using non-spatialized earcons when several aspects of the environment are spatialized using audio (reduces the complexity of the environment).
• It may be difficult to utilize strategies that have proven effective in the real world in interactive applications. For example, metronomes are an effective real world option for pace setting. But due to the complexity of metronome implementation, such techniques may not prove as effective for pace setting in virtual environments.

Acknowledgements

This material is based upon work supported in part by the Office of Naval Research under its Virtual Technologies and Environments (VIRTE) program. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views or the endorsement of ONR.

Bibliography

Bartscherer, M.L., & Dole, R.L. (2005). Interactive Metronome Training for a 9-year-old boy with attention and motor coordination difficulties. Physiotherapy Theory and Practice 21(4), 257-269.

Boyle, A. J., Wilson, A. M., Connelly, K., McGuigan, L., Wilson, J., & Whitbourn, R. (2002). Improvement in timing and effectiveness of external cardiac compressions with a new non-invasive device: the CPR-Ezy. Resuscitation, 54(1), 63-7.

Chen, Y., Repp, B.H., & Patel, A.D. (2002). Spectral decomposition of variability in synchronization and continuation tapping: Comparisons between auditory and visual pacing and feedback conditions. Human Movement Science, 21, 515-532.

Day, R., Holland, S., Bowers, D., & Dil, A. (2004). Using Spatial Audio in Minimal Attention Interfaces: Towards an Effective Audio GPS Navigation System. Technical Report. Available online: http://computing-reports.open.ac.uk/index.php/content/download/150/887/file/TR2004_08.pdf, accessed October 5, 2006.

European Telecommunications Standards Institute [ETSI]. (2002). Human factors: guidelines on the multimodality of icons, symbols, and pictograms (Rep. No. ETSI EG 202 048 v 1.1.1). Sophia Antipolis Cedex, France.

Jones, D., Stanney, K.M., & Fouad, H. (2005). An Optimized Spatial Audio System for Virtual Training Simulations: Design and Evaluation. The 11th Internal Conference on Auditory Displays (ICAD), Ireland, July 6-9.

Kaplan, R. (2002). Rhythmic Training for Dancers, Human Kinetics, Champaign, IL.

Karageorghis, C.I., & Terry, P.C. (1997). The Psychophysical Effects of Music in Sport and Exercise: A Review. Journal of Sport Behavior, 20(1), 54-68.

Kern, K.B., Sanders, A.B., Raife, J., Milander, M.M., Otto, C.W., & Ewy, G.A. (1992). A study of chest compression rates during cardiopulmonary resuscitation in humans: the importance of rate-directed chest compressions. Archives of Internal Medicine, 152(1), pp. 145-149.

Kolers, P.A., & Brewster, J.M. (1985). Rhythms and Responses. Journal of Experimental Psychology: Human Perception and Performance, 11(2), 150-167.

Kramer, G. (1994). An introduction to auditory display. In G. Kramer (Ed.), Auditory Display (pp. 1-77). Reading, MA: Addison-Wesley.

Kurtz, S., & Lee, T.D. (2003). Part and whole perceptual-motor practice of a polyrhythm. Neuroscience Letters 338, 205–208.
Libkuman, T. M. , Otani, H.., & Steger, N. (2002). Training in Timing Improves Accuracy in Golf. Journal of General Psychology, 129(1), pp. 77-96. Available online: http://www.findarticles.com/p/articles/mi_m2405/is_1_129/ai_86431660/pg_6, accessed December 21, 2005.
Loomis, J.M., Golledge, R.G., & Klatzky, R.L. (1998). Navigation system for the blind: Auditory display modes and guidance. Presence: Teleoperators & Virtual Envimnments, 7, 193-203.
Meegan, D.V., Aslin, R.N., & Jacobs, R.A. (2000). Motor timing learned without motor training. Nature Neuroscience, 3. Available online: http://www.bcs.rochester.edu/people/robbie/meeganaslinjacobs.nn00.pdf.
Repp, B.H., & Penel, A. (2002). Auditory Dominance in Temporal Processing: New Evidence From Synchronization With Simultaneous Visual and Auditory Sequences. Journal of Experimental Psychology: Human Perception and Performance, 28(5), 1085-1099.
Repp, B. H. (2006). Does an Auditory Distractor Sequence Affect Self-Paced Tapping? Acta Psychologica 121, 81-107.
Schreiber, F.A. (1994). Is Time a Real Time? An Overview of Time Ontology in Informatics. In W.A. Halang, & A.D. Stoyenko (Eds.), Real Time Computing, Springer Verlag NATO-ASI Vol. F127, 283-307.
Stanney, K.M., Kingdon, K., Graeber, D., & Kennedy, R.S. (2002). Human performance in immersive virtual environments: Effects of duration, user control, and scene complexity. Human Performance, 15(4), 339-366.
Thaut, M.H., McIntoshn, G.C., Rice, R.R., Miller, R.A., Rathbun, J., & Brault, J.M. (2004). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. Movement Disorders, 11(2), 193 – 200.
Thaut, M.H. (2005). Rhythm, music, and the brain. Routledge, Taylor and Frances Group, New York: NY.
USArmy - Department of Army (2003). Urban Operations, Field Manual (FM3-06). Available online: http://www.globalsecurity.org/military/library/policy/army/fm/3-06.
Wiens, J.A., Martin, S.G., Holthaus, W.R., & Iwen, F.A. (1970). Metronome timing in behavioral ecology studies. Ecology, 51(2), 350-352.
Wijnalda, G., Pauws, S., & Vigoli, F. (2005). A Personalized Music System for Motivation in Sport Performance. Pervasive Computing, 26-32.