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TEMPORAL INTERFACE DESIGNS FOR MODELING AND SIMULATION: REDUCING DISPLAY CLUTTER BY TEMPORAL FUSION

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ABSTRACT

This research examines employing *"Temporal Fusion"* to reduce clutter confusion associated with dynamic information displays used in C2 operations. The intent here is to design timing formats to aid targeting attention and memory Eleven subjects performed an attentionally demanding short-term (ST) memory task. Two different timing formats are used to carry memory set items. Task irrelevant items are present and timed to occur either synchronously with memory set items or asynchronously. Results indicate that dynamic irrelevant information added to the display can affect recognition memory. Performance facilitation is best when task irrelevant item timing is the same as memory set timing. These data suggest application of certain timing formats may play an important role in reducing clutter confusion by guiding attention and aiding memory when processing multiple sources of dynamic information. These data also have implications when designing interfaces for modeling and simulation tools.

1 INTRODUCTION

Effective management of high priority tasks in a rapidly changing environment is an especially important concern in the military. An operator's failure to update, or take appropriate action in a timely manner, can have serious consequences. The dynamically complex work environment of the Air Battle Management work domain is such an environment. Here the mission crew commander monitors the tactical situational picture on an often cluttered and confusing Situational Display (SD). For example, the SD provides real-time information of moving tracks representing air and ground assets of friendly and enemy forces, as well as, unidentified tracks that could be "friends or foes." While maintaining SA of the tactical situation picture, the commander must also engage in intermittent tasks that involve: creating associations between coalition assets and targets ("hooks"); coordinating air-air-refueling; and responding to warnings. The inherent display clutter can easily lead to distraction and consequently loss of work thread continuity, especially under time pressure. Therefore, this research seeks to address the following operational questions:

- Can the reduction of SD clutter confusion be accomplished without redesigning the display?
- Can structured timing formats be applied to sequentially occurring information to reduce the problem of clutter confusion without introducing additional distraction?

1.1 Background

Previous research suggests that the answer to these questions is "YES!" Skelly (2003) argues that a *temporal interface* naturally emerges between the viewer and the environment anytime we attend and process dynamic information. And further, temporal interfaces possess dynamic structures (spatio-temporal relationships) that can affect "how" and "what" information we perceive, select, and remember. This is because when we are exposed to persisting timing relationships associated with patterns of environmental stimulation (e.g., auditory or dynamic visual information flows) we can become "tuned" or synchronized to these timing relationships (see Jones 1976; 2004). In essence, we become primed to pickup and use these temporal relationships to anticipate upcoming events and reduce uncertainty when interacting with our environment (see Skelly 1992, Skelly and Jones 1990, 2004, and 2002, for extended descriptions of experimental evidence and theoretical approach).

Skelly (2003) demonstrates that our sensitivity to invariant timing relationships can be exploited. That is, designed temporal interfaces can be created and applied effectively in operational displays to aid decision making and enhance perceptual discrimination with appropriate attentional deployment. The present research examines whether a new type of temporal interface design, *temporal fusion*, has potential for aiding operator situational awareness by reducing display clutter confusion.

2 TEMPORAL FUSION HYPOTHESES

The term "temporal fusion" refers to two different ways that timing patterns, possessing certain structural properties, may become *fused* with visual stimuli to provide detection, prediction, and comprehension enhancement for task relevant information. The first application which is designated as Level 1 Temporal Fusion refers to creation of timing patterns based on specific rhythmic ratios applied to a single source of task relevant information. The following hypothesis is tested to determine whether there is evidence supporting the idea that certain temporal pattern structures have been *fused* with the task relevant information items.

2.1 Level 1 Temporal Fusion Hypothesis

The four following assumptions apply in this case. First, more coherent rhythmic parameters (e.g., whole vs. fractionated relative time ratios) create time patterns with high predictability for "when" and "where" information will occur. Second, highly predictable a time patterns will bond or "fuse" with visual stimuli resulting in less attentional energy expended in remembering these items. Third, when a strong coherent rhythm fuses with task relevant stimuli, then memory for this information should be enhanced. Finally, a timing pattern with weak rhythmic coherency will result in an increase of attentional energy expended. Thus, if rhythm coherency is weak, it should be more difficult for the operator to remember task relevant items, as compared to timing patterns based on structurally coherent rhythmic parameters. Since a structurally coherent rhythm is expected to reduce attentional energy required to remember task relevant items, these timing patterns should also result in memory task performance facilitation (e.g., faster response times and fewer errors).

The second Temporal Fusion application is designated as Level 2 and involves examination of how "adding" temporally patterned irrelevant information to an already cluttered display may affect performance in a memory task. Here, specific timing patterns are applied to both task relevant and task irrelevant information.

2.2 Level 2 Temporal Fusion Hypothesis

It is expected that when both task relevant and task irrelevant information are presented synchronously with the same timing pattern (yielding a Compatible timing combination) task performance will be superior to Incompatible timing combination where the task relevant and task irrelevant information are presented to the viewer with different time patterns. It is expected that when different information sources share the same structural time pattern (compatible time combination) that should either allow the operator to ignore irrelevant information by making it less distracting (i.e., the time patterns will become *fused)*, or time pattern fusion will reinforce and highlight temporal predictability of "when" memory set items will appear. That is, enhance attentional readiness to pickup up information. On the other hand, when task relevant and irrelevant information are formatted with different time patterns, then *temporal fusion* should NOT occur. Here, if the ball clusters appear within the more structurally coherent timing pattern, it is expected that this combination may increase distraction by attention becoming involuntarily attracted (or captured) resulting in memory task performance decrements. However, if the more coherent timing pattern carries the memory set items and the less coherent time pattern carries the irrelevant ball clusters, then distraction effects should be ameliorated.

3 METHODOLOGY

3.1 Task Description

The task uses a dynamic paradigm created from two classic paradigms, the Sternberg Memory Task and the Posner Classification Task. In this hybrid paradigm, the memory set is composed of 5 elements, combinations of shapes and letters. Elements of the memory set are presented sequentially and carried by either of two different timing patterns; one with high rhythmic coherency; the other a more irregular rhythm with weaker structural coherency. The memory set sequence is repeated 5 times, appearing to the viewer as a continuous flow of discretely occurring events. Some elements in the set appear "coupled," i.e., a letter can sometimes appear inside a shape. However, the Target always appears as a single element and could be either a letter or shape comprising the coupled event. The task requires the subject to judge whether the target is a *Physical Match* with any member of the memory set. For example, if the letter "A" appears in the memory set and "a" is a target, the correct response is NO. Memory set stimuli are shown in Figure 1.

3.2 Experimental Sessions

Part 1

This is a baseline condition designed to examine task performance in the memory task where the memory set (relevant information stream) is presented in either of two rhythmic timing patterns; one is based on a 3:2 rhythmic ratio and the other on the 4:3 ratio. The 3:2 rhythmic ratio yields a more coherent (i.e., predictable) rhythm than the time pattern produced with the 4:3 ratio. During baseline trials, the memory set items occur against two different backgrounds. Half of the trials are presented against a solid colored background with no other distracter items on the screen. The other half of session trials occur against a cluttered background. Here, memory set elements appear against a static map background where aircraft icons are moving in different directions, thus creating continuous motion distracter elements. The different background trials are randomized before presentation to the viewer.

Figure 1: Letters and Shapes Stimuli Used to Create Memory Sets

Part 2

In this condition, an additional dynamic information stream is added to the display. Here, groups of balls appear with every memory task trial. The ball clusters can appear in any of six different locations and viewers are instructed to ignore them, hence these dynamic ball clusters are task *irrelevant* information. Figures 2 and 3 show combinations of task relevant and irrelevant information against plain and cluttered backgrounds respectively.

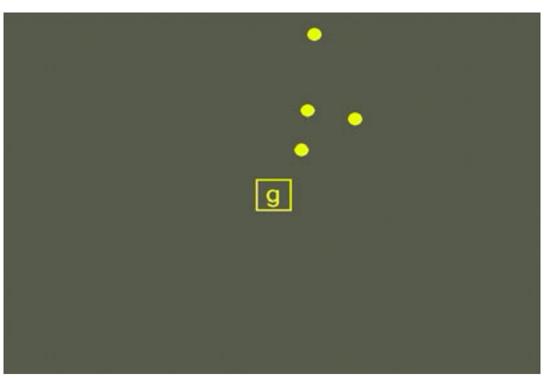

Figure 2: Static Representation of Dynamic Short-Term Memory Task Trial with Plain Background and Task Irrelevant Balls

Figure 3: Static Representation of Dynamic Short-Term Memory Task Trial with Cluttered Background and Task Irrelevant Balls

3.3 Design

This is a Within Subject design with the following factors:

- Stimuli Timing. Two rhythmic time parameters, based on 3:2 and 4:3 rhythm ratios, create sequences of discretely occurring stimulus events for both the Memory Set items (task relevant) and Ball Clusters (task irrelevant). Stimulus duration is held constant for both memory set items and ball clusters.
- Display Background: Solid or Cluttered.
- Timing Combinations: Compatible or Incompatible timing combinations between memory set items and ball clusters yielding 4 unique combinations.
- Judgment: YES (Target is in Memory Set); NO (Target is not in Memory Set).
- Sessions: Part 1 – Baseline Session where only Memory Set elements are presented. Part 2 - Ball Clusters (irrelevant to task) are presented with during each ST Memory Task trial.
- Dependent Variables: Response Times (RTs) and Proportion Correct (PC).

3.4 Procedure

Eleven subjects participated in both study sessions. Memory set elements are presented on high resolution 21” plasma screens. Stimuli are precisely timed with millisecond accuracy. There are a total of 64 trials in each session and sessions last approximately thirty-five minutes each. Trials are presented in a continuous manner (i.e., they are not self-paced) with four short breaks within a session. Subjects are instructed to respond as quickly as possible with their decision as to whether the Target element had appeared within the memory set; but, subjects were cautioned not to sacrifice accuracy. All subjects received a practice period (approx. 15-20 minutes prior to the Baseline session). Sessions were separated by a minimum three hour interval to avoid fatigue effects as the task was designed to be attentionally demanding.

4 RESULTS

4.1 Effects Stimuli and Response Types

There are a number of significant effects associated with Memory Set stimuli combinations (letters and shapes) of and Judgment category (YES/NO). First, subjects' response times (RTs) are significantly faster when the target was not a member of the memory set and correct response was NO, $F(1,892)=5.32$, $p<.02$. The largest significant main effects are related to Target Type for both mean RTs and PC. Response times are significantly faster when Target was a Letter, as compared to a Shape (794 msec vs. 901 msec), $F(1, 892)=57.64$, $p<.0001$. There are also more response errors when the Target was a Shape, e.g.,79 PC versus 93% PC compared to when Target was a letter, $F(1,892)=34.16$, $p<.0001$. Subjects did report: (1) that it was easier to determine that a Target was NOT in a memory set than when it was in the set and (2) that decisions with a Shape target were harder than a Letter target.

4.2 Timing Effects: Memory Set (task relevant) and Ball Clusters (task irrelevant)

Results indicate as subjects became more experienced with the dynamic memory task, both response times (RTs) and proportion correct responses (PC) improve. There is a significant main effect that differentiates RT performance between Baseline and Experimental sessions shown in Figure 4. This figure reveals that when a second dynamic information stream is added to the memory task environment (in this case the irrelevant ball clusters) RTs decrease, $F(2,892)=3.49$, $p<.03$.

An important, but non significant effect related to this main effect, is the interaction between memory set timing and the irrelevant ball cluster timing shown in Figure 5, $F(1,344)=1.81$, $p<0.1$. Here, RTs do not differ when the two timing streams are Compatible (same rhythmic time ratios). However, note the change in RTs when timing combinations are Incompatible. When memory set items appear in a 4:3 rhythmic timing and ball clusters appear within a 3:2 rhythm, RTs increase. However, when the reverse Incompatible condition is presented, i.e., task relevant stimuli in a 3:2 rhythmic timing pattern and irrelevant stimuli in a 4:3 rhythm, RTs decrease

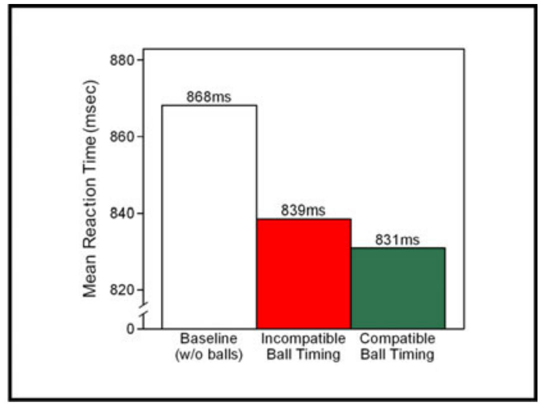

Figure 4: Response Times (RTs) as a Function of Irrelevant Stimuli Presence or Absence During Short-Term Memory Task Trials.

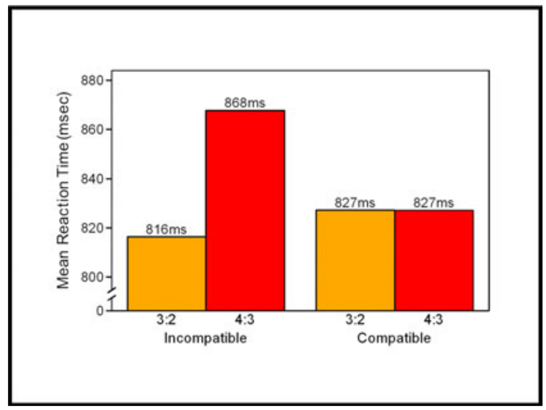

Figure 5: Mean Response Times (RTs) as a Function of Memory Set Timing and Compatible/Incompatible Irrelevant Stimuli Timing.

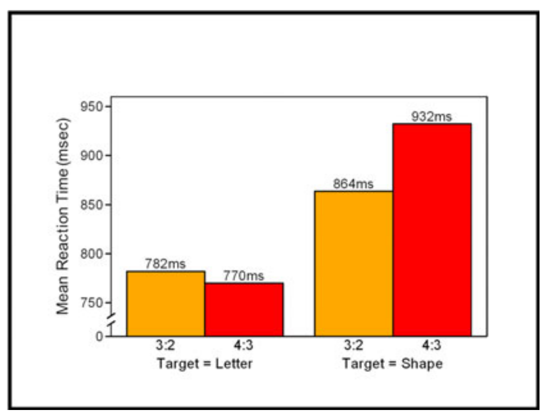

Figure 6: Mean Response Times (RTs) as a Function of Memory Set Timing and Target Type.

There is also a significant interaction between memory set timing and whether the Target is a Letter or Shape

F(1,344)=3.59, p,<05. In this interaction shown in Figure 6, RTs significantly increase when the Target is a Shape and the memory set items are presented in the 4:3 rhythmic timing pattern as compared to the memory set presented with a 3:2 rhythm. Response times are fastest when the Target is a Letter in both memory set timing conditions. PC scores also show the same trend with higher PC scores when the Target is a Letter for both timing conditions and lowest when the Target is a Shape. These results reflect the significant stimuli effects presented earlier.

5 CONCLUSIONS

Research questions relate to whether there is present evidence to support the notion that certain rhythmic ratio parameters will "*fuse*" with visual stimuli to create dynamic contexts that may aid memory for items in a Short-Term (ST) memory task. These results do provide evidence that *temporal fusion* can function as a memory aid. However, application of these techniques is a cautionary tale. Results are interpreted according to the Temporal Fusion Hypotheses presented earlier.

5.1 Temporal Fusion – Level 1 Support

- Evidence that both rhythmic time ratios, 3:2 and 4:3 do bond or "*fuse*" with task relevant stimuli to affect RT performance and PC scores as subjects engage in a Short-Term memory task. Performance differences are gradually revealed the longer subjects are exposed to certain timing structures. This suggests that *temporal fusion* will become stronger the longer an individual is exposed to these dynamic task contexts.
- Performance profiles do show greater improvement when the rhythmic time ratio applied is more structurally coherent, i.e., the 3:2 rhythmic ratio vs. the 4:3 rhythmic ratio parameter. Situations that relate to interactions with task relevant stimuli type do create some speed/accuracy trade-offs.

5.2 Temporal Fusion – Level 2 Support

- Adding a dynamic irrelevant information stream to a memory task can facilitate processing dynamically presented task relevant information.
- Application of certain timing parameters to task irrelevant information can serve to either aid ignoring irrelevant stimuli or create additional display distractions.
- When task relevant and irrelevant information are presented with the same timing pattern (compatible timing condition), task performance benefits occur.
- When task relevant and irrelevant information possess different timing patterns, structural coherence of specific timing parameters determines whether irrelevant information can be ignored or becomes a distracter. If task relevant information possesses the more coherent and thus, stronger *fusing* time parameter of the two information stream, then viewers are better able to ignore irrelevant stimuli. However, if the reverse situation applies, i.e., irrelevant information possesses the stronger fusing time parameter, then task performance is likely to suffer.

5.3 Research Implications

In sum, *temporal fusion* techniques do have potential applicability to function as an aid to perception, comprehension, and memory in high workload operational environments; especially those mission tasks requiring simultaneous tracking and management of critical mission events. Further, these data do suggest potential applications for usage in simulation environments, especially for training purposes. Specifically, when temporal manipulations of dynamic information are designed to exploit how we naturally resonant to certain dynamic patterns in our environment, there is less expenditure of cognitive energy. The result is more efficient deployment of attention (e.g., lessening cognitive overload and time on task effects) and discrimination of critical task relevant information.

Further research is needed to fully explore and exploit the benefits of these techniques for application in different operational environments and tasking. To this end, we are continuing to explore this line of research in multi-modal applications.

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