Assessment of Human Vulnerability in a Touch-screen Game; Metrics and Analysis
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Problem Definition

• Human under excessive stress/mental workload prone to error and they are vulnerable [1].
• Affective computing infers human vulnerability by analyzing human physiological responses [8].
• However, studies show that affective computing → NOT RELIABLE [2]

Objective

• We propose an alternative way to sense human mental states while interacting with a machine.
• HYPOTHESIS: Humans’ behavioral patterns must be affected by task difficulty changes.
• We verify the reliability of the proposed behavioral measurements to infer human mental states using the performance and physiological metrics, pNN50 as a baseline.

Air Traffic Management Game

An air traffic management game within MATLAB is designed with two levels of difficulty, namely Easy and Difficult, to induce different workload demands.

Figure: Left: Easy Game. Right: Difficult Game. Red and Blue arrow: un-assigned and assigned trajectories.

Experimental Protocol

• Easy (E) 1 and 2 are identical to the easy level.
• Rest (R) 1 and 2 are the rest period: Subjects relaxed and did not play the game.

Performance Metric

Subjects’ Goal

Object Target

A B C

Behavioral Metric

Effort

kinetic energy for a lumped point mass

mass \( m \) unknown,

\( \Delta m \) removed from energy calculation

Sum of the Strokes

Energy in Game \( g \)

Mean Energy

of Strokes in Game \( g \)

Total Energy of Stroke

\[ TB_g = \sum_{i=1}^{N_g} \Delta E_i \]

\[ MB_g = \frac{TB_g}{N_g} \]

Stroke Duration & Stroke Delay Time (Decision Making) [5-7]

(Nick-Hynman Law and Fitt’s Law)

Stroke Duration

\[ TD_g = t_{f_i \_end} - t_{i \_begin} \]

Mean Stroke Duration in Game \( g \)

\[ MSD_{g} = \frac{1}{N_{g}} \sum_{i=1}^{N_{g}} TD_{i} \]

Mean Stroke Delay in Game \( g \)

\[ MSD_{g} = \frac{1}{N_{g}} \sum_{i=1}^{N_{g}} TD_{i} - 1 \]

Results: Performance Metrics

• Fewer strokes, drawn faster in D & more strokes drawn slower in E1 and E2.
• Longer decision-making time to decide to assign the airplanes to the airports in D [7].

Results: Behavioral Metrics

• pNN50 is significantly affected by the game difficulty.
• pNN50 shows subjects’ subjective perception of game difficulty [4].
• pNN50 the lowest in D & larger in E1 and E2 → inverse correlation to mental workload.
• Game order has non-linear effect on pNN50 → Dependent on game order.

Conclusion

• ME and MSD show strong correlation with performance and physiological (pNN50) metrics.
• Behavioral metrics can differentiate between difficult and easy tasks encountered by the subjects.
• Behavioral metrics infer subjects’ task load increases, and thereby to infer subjects vulnerability.

References


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