

**ANALISA PENGARUH INTERVENSI AKOMODASI-KONVERGENSI
TERHADAP PARAMETER *MENTAL FATIGUE* INTRA INDIVIDU PADA
AKTIVITAS *NEARWORK* DENGAN TES PAULI BERBASIS *VIRTUAL REALITY*
(VR)**

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ABSTRAK

Latar Belakang: Aktivitas *nearwork* berbasis layar 2D dalam masa yang panjang dapat memicu kelelahan visual dan mental fatigue yang berdampak pada penurunan performa kognitif. Aktivitas akomodasi–konvergensi mata menjadi mekanisme yang berpengaruh pada kondisi ini. Teknologi *virtual reality* (VR) berpotensi dapat dipergunakan untuk mengintervensi dengan mengeliminasi kebutuhan akomodasi–konvergensi.

Tujuan: Menganalisis pengaruh intervensi eliminasi akomodasi–konvergensi mata dengan perangkat VR terhadap parameter mental fatigue pada intra-individu dalam aktivitas *nearwork*.

Metode: Penelitian dengan desain crossover intra-individu melibatkan 20 subjek laki-laki sehat usia 18–25 tahun. Setiap subjek menjalani dua Perlakuan: (1) Tes Pauli berbasis layar 2D, dan (2) Tes Pauli berbasis 3D VR. Parameter mental fatigue dinilai menggunakan multi-biomarker objektif, meliputi performa Tes Pauli, diameter pupil, latensi dan amplitudo P300 ERP, serta gelombang EEG (theta frontal, alpha parietal dan oksipital). Analisis statistik menggunakan Linear Mixed-Effects Model (LMEM).

Hasil: Faktor durasi dan waktu berpengaruh signifikan terhadap menurunnya diameter pupil ($p < 0,001$) dan perlambatan latensi P300 ($p = 0,034$), menunjukkan perkembangan mental fatigue seiring durasi *nearwork*. Tidak ditemukan perbedaan signifikan antara kondisi 2D dan 3D VR pada parameter gelombang alpha dan theta dan amplitudo P300. Tetapi menunjukkan kenaikan performa kognitif yang ditunjukkan dengan hasil Tes Pauli dengan perbedaan bermakna, antara kondisi VR yang dapat mempertahankan dan perbaikan performa kognitif secara signifikan dibandingkan kondisi layar 2D ($p = 0,017$).

Kesimpulan: Intervensi eliminasi akomodasi–konvergensi berbasis 3D VR pada aktivitas *nearwork* tidak menghambat perkembangan mental fatigue secara neurofisiologis, namun memberikan keuntungan perbaikan performa kognitif. VR berpotensi menjadi alternatif media *nearwork* tanpa meningkatkan atau menurunkan risiko mental fatigue secara signifikan dibandingkan berbasis layar 2D.

Kata Kunci: akomodasi, konvergensi, *nearwork*, *virtual reality*, *mental fatigue*, Tes Pauli, P300, EEG.

**ANALYSIS OF THE EFFECTS OF ACCOMMODATION–CONVERGENCE
INTERVENTION ON INTRA-INDIVIDUAL MENTAL FATIGUE PARAMETERS
DURING NEAR-WORK ACTIVITIES USING A VIRTUAL REALITY (VR)-BASED
PAULI TEST**

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ABSTRACT

Background: Prolonged 2D screen-based nearwork activities can induce visual fatigue and mental fatigue, leading to a decline in cognitive performance. Ocular accommodation–convergence activity is a key mechanism contributing to this condition. Virtual reality (VR) technology has the potential to be used as an intervention by eliminating the need for accommodation–convergence.

Objective: To analyze the effect of eliminating ocular accommodation–convergence using a VR device on mental fatigue parameters within individuals during nearwork activities.

Methods: This study employed an intra-individual crossover design involving 20 healthy male subjects aged 18–25 years. Each subject underwent two conditions: (1) a 2D screen-based Pauli Test and (2) a 3D VR-based Pauli Test. Mental fatigue parameters were assessed using objective multi-biomarkers, including Pauli Test performance, pupil diameter, P300 ERP latency and amplitude, and EEG waves (frontal theta, parietal and occipital alpha). Statistical analysis was performed using a Linear Mixed-Effects Model (LMEM).

Results: Duration and time factors had a significant effect on pupil diameter reduction ($p < 0.001$) and P300 latency prolongation ($p = 0.034$), indicating the progression of mental fatigue with increasing nearwork duration. No significant differences were found between 2D and 3D VR conditions in alpha and theta wave parameters or P300 amplitude. However, cognitive performance, as measured by the Pauli Test, showed a significant improvement under the VR condition, which was able to maintain and enhance cognitive performance compared with the 2D screen condition ($p = 0.017$).

Conclusion: A 3D VR-based intervention eliminating accommodation–convergence during nearwork activities does not inhibit the neurophysiological development of mental fatigue, but it provides benefits in improving cognitive performance. VR has the potential to serve as an alternative nearwork medium without significantly increasing or decreasing the risk of mental fatigue compared with 2D screen-based media.

Keywords: accommodation, convergence, nearwork, virtual reality, mental fatigue, Pauli test, P300, EEG.