Change in bilateral motor synergies during bimanual force control task by level of visual information

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BACKGROUND

***Newell's constraint model*:**
bimanual coordination is influenced by three constraints: (a) environmental, (b) task, and (c) organism. We manipulated one constraint (a) visual gain magnitude.

***Bilateral motor synergies (UCM hypothesis)*:**
(a) human central nervous system (CNS) selects infinite solutions and then combines them into the combinations that denoted motor synergies
(b) ratio of good variability relative to bad variability
(c) alternative coordination measurement

PURPOSE

Our purpose is to investigate bimanual force control capability changes in different visual information conditions across the trials. Particularly, we used UCM theory to quantify bilateral motor synergies.

METHODS

Participants
13 healthy young adults : (age M±SD = 25.6±5.6)
13 right-handed

Bimanual force control: index finger abduction
(a) target level: 20% of MVC (three MVC trials)
(b) four visual gains: 8, 80, 256, and 512 pixels/N
(c) 9 experimental trials × 4 visual condition = 36 total trials (during 15 s)

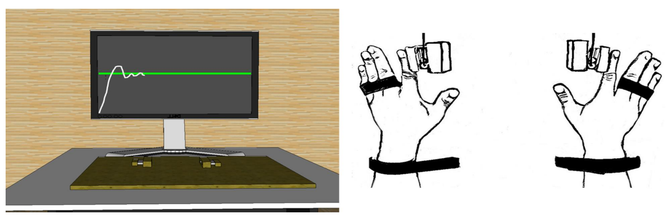

Fig. 1. Abduction movements of index fingers during bimanual force control

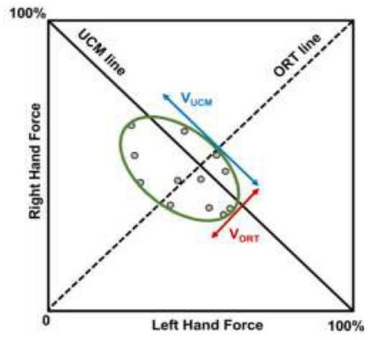

Fig. 2. Good and bad variability calculations

Data analyses
Middle 11 s of force control: removed initial adjustment (3 s) and early termination (1 s)

Bilateral motor synergies: within a trial (Fig. 2)

$$V_{Index} = \frac{V_{UCM}/df_{UCM} - V_{ORT}/df_{ORT}}{V_{TOT}/df_{TOT}}$$

$$V_{Index}(Z-transformed) = 0.5 \times \ln\frac{2+V_{Index}}{2-V_{Index}}$$

Bimanual force control capability

Force accuracy: Root-Mean squared error (RMSE)

Force variability: Standard Deviation (SD)

Force regularity: Greater sample entropy (SampEn) values indicates irregular force signals.

$$\textbf{SampEn}\ (x, m, r, N) = \ln\left[\frac{C_m(r)}{C_{m+1}(r)}\right]$$

Correlation between bilateral motor synergies and force control: Pearson's linear correlation coefficients

Statistical analyses

One-way repeated measures ANOVAs: four visual gain condition; 8 vs. 80 vs. 256 vs. 512 pixels/N.

Post hoc procedure: Bonferroni's pairwise comparisons

RESULTS

Bilateral motor synergies

Value of bilateral motor synergies (V_{Index}) 80 pixels/N (P = 0.007), 256 pixels/N(P = 0.001), and 512 pixels/N (P < 0.001) were significantly greater than those at 8 pixels/N (Fig. 3. A).

Bimanual force control capability

RMSE and SD 512 pixels/N were significantly lower than at 8 pixels/N (P = 0.020), (P = 0.033) (Fig. 3. B and C). SampEn at 256 pixels/N (P = 0.013), 512 pixels/N (P = 0.001) were significantly increased greater than those at the 8 pixels/N (Fig. 3. D).

Correlation

Increased V_{Index} was significantly correlated with decreased RMSE (r = -0.59, P <0.001), less SD (r = -0.53, P <0.001), and increased SampEn (r = 0.56, P <0.001) (Fig. 4).

DISCUSSION

The current findings indicate that increased visual gains in young adults influence positive effects on bimanual coordination between the trials that required higher motor control abilities.

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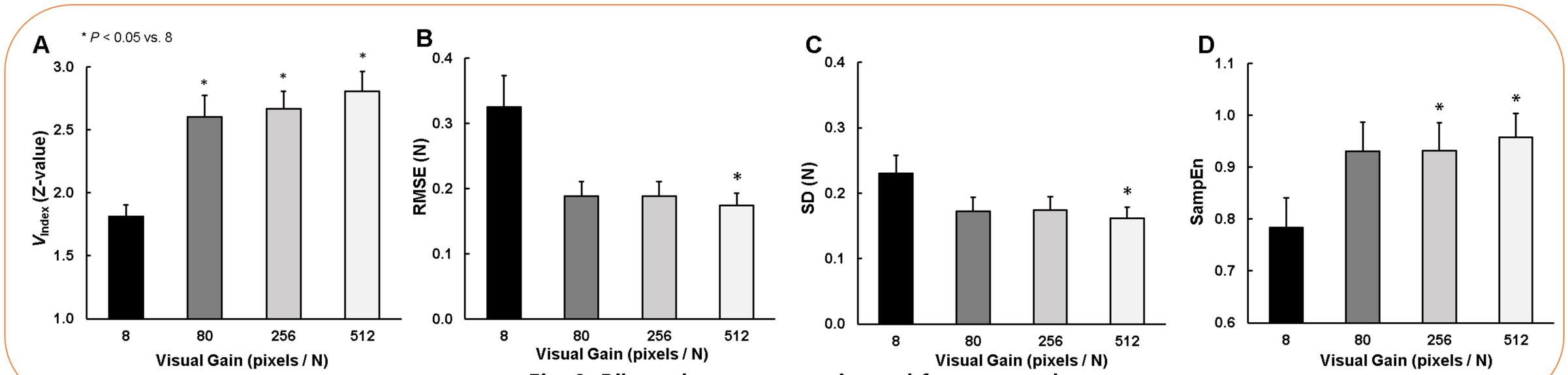

Fig. 3. Bilateral motor synergies and force control

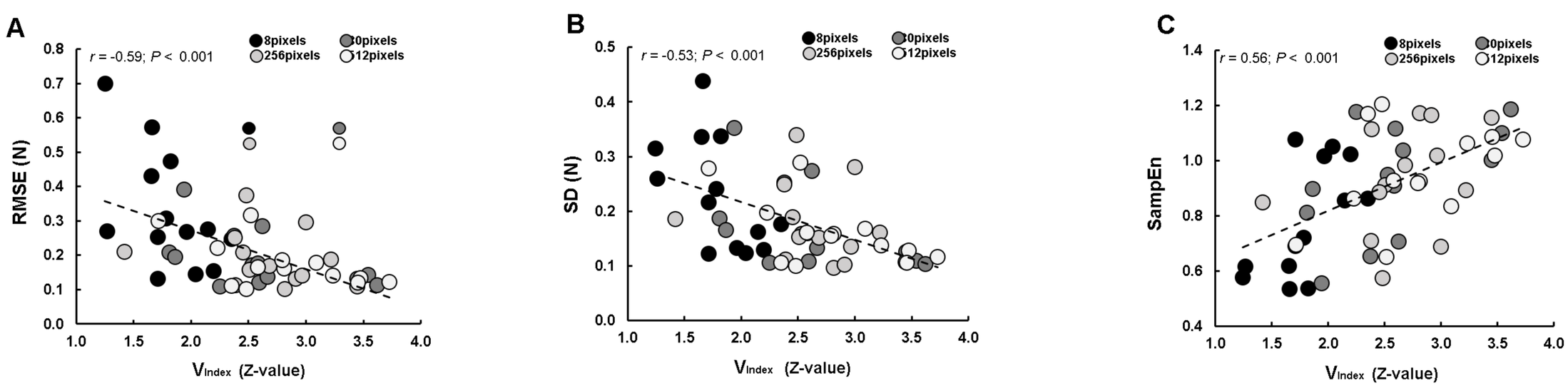

Fig. 4. Correlation between bilateral motor synergies and force control