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LETTER TO THE EDITOR

Beyond group averages: why motor control studies must address population and individual heterogeneity

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TO THE EDITOR: Kim et al. (1) make an important conceptual contribution by distinguishing force variability from force smoothness during isometric contractions, demonstrating that these metrics respond differently to visual gain manipulation. However, the study suffers from two fundamental problems that undermine its scientific validity: *1*) a demographically opaque convenience sample of 14 participants presented as revealing universal principles of human motor control, and *2*) visible individual heterogeneity in the data that is completely ignored in favor of group averages. These issues exemplify what I term the "dual diversity crisis" in neuroscience research—the simultaneous neglect of both population diversity and brain diversity.

POPULATION DIVERSITY NEGLECT

Kim et al. (1) provide minimal demographic characterization ["14 young adults (20 ± 1.4 yr; 10 females)"] yet frame their findings as universal: "force variability and force smoothness are distinct motor control features" with "important implications for understanding sensorimotor integration and designing targeted interventions". Their conclusion states these findings "highlight distinct physiological mechanisms" and "suggest separate cortical strategies" applicable to human motor control generally.

This represents a validity threat that has become endemic in neuroscience. Motor control mechanisms may vary systematically across populations due to neuromuscular physiology, developmental motor experiences, cultural movement practices, and genetic variation in sensorimotor processing (2, 3). Yet the authors never acknowledge this possibility. Their limitations section mentions inability to generalize to older adults or clinical populations but never questions whether their young adult convenience sample itself is representative.

Recent work has documented profound failures of generalization when findings from homogeneous samples are applied to diverse populations (4, 5). In neuroimaging specifically, researchers have shown that brain-behavior relationships established in Western, educated, industrialized, rich, and democratic (WEIRD) samples often fail to replicate in non-WEIRD populations (4). The burden is on researchers making universal claims to demonstrate universality—not to assume it from a sample of 14 university students.

BRAIN DIVERSITY OVERSIGHT

Perhaps more troubling, Kim et al.'s (1) data show substantial individual variation that they systematically ignore. Fig. 3 in their study reveals obvious scatter in individual responses. Fig. 4 in their study shows correlations between force smoothness (YANK_RMS) and variability (SD) ranging from $R^2 = 0.01$ to $R^2 = 0.32$ across conditions—indicating the association between these constructs differs dramatically across individuals. Although Figs. 6 and 7 commendably display individual data points in correlation plots, these still examine associations between derived measures within the same narrow demographic, precluding assessment of whether these associations hold across different populations or neurobiological phenotypes. Tables 1 and 2 from their study show correlations between force/electromyogram power and motor outcomes ranging from $r = -0.58$ to $r = 0.90$, suggesting heterogeneous neural strategies.

Yet Kim et al. (1) perform no individual-level analyses. They never ask: Do all participants show reduced variability and impaired smoothness with high-gain feedback? What distinguishes participants who show strong effects from those who do not? Do the claimed "distinct physiological mechanisms" hold within individuals, or only at the group level?

This aggregation fallacy has been identified as a critical problem in neuroscience (6, 7). Group-level statistical significance does not imply the effect applies uniformly to individuals. When visible heterogeneity is present—as it clearly is in Kim et al.'s (1) study data—researchers must examine individual response patterns, classify responders versus nonresponders, and identify predictors of individual differences. Averaging over heterogeneity to claim "clear and opposing effects" misleads readers about the reliability and applicability of findings.

The conceptual framework of Kim et al.'s (1) own study demands individual-level analysis. If variability and smoothness truly reflect "separate physiological processes" (1), then

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individual differences in these processes should be characterized. Some individuals might show the group-level pattern (reduced variability, impaired smoothness); others might show only one effect; still others might show neither. Without this analysis, we cannot know whether the dissociation between variability and smoothness is a robust phenomenon or an artifact of averaging.

COST OF IGNORING DIVERSITY

These problems have real consequences. Kim et al. (1) suggest their findings inform "designing targeted interventions to improve motor performance in tasks requiring precise and sustained force control." But interventions designed from group averages of 14 demographically opaque participants are unlikely to generalize effectively. Clinicians treating diverse patient populations need to know: For whom do these effects hold? Who might respond differently? What predicts individual responses?

The extensive speculation about cortical mechanisms based on group-level correlations is similarly problematic. In their study, Kim et al. (1) propose that reduced smoothness reflects "cortically-driven oscillatory input to the motor neuron pool" and "heightened cortical modulation" (1). But if different individuals use different cortical strategies—as the heterogeneous correlations suggest—these group-level mechanistic claims may be misleading.

PATH FORWARD

I do not dispute the value of distinguishing force variability from smoothness. This conceptual contribution merits publication. However, the empirical work requires fundamental revision:

Regarding population diversity:

1) Report comprehensive demographics;
2) Acknowledge limitations of convenience sampling from a single site;
3) State conclusions as "In this sample…" rather than as universal principles;
4) Explicitly note that validation across diverse populations is needed before claiming implications for "sensorimotor integration" generally.

Regarding brain diversity:

1) Report distributions of individual responses, not just group means;
2) Classify participants as responders/non-responders for each effect;
3) Test whether the variability-smoothness dissociation holds within individuals;
4) Explore predictors of individual differences;
5) Acknowledge that group-level mechanisms may not apply uniformly.

These are not onerous requirements. They represent basic scientific practice: characterize your sample, examine heterogeneity in your data, constrain conclusions to what the evidence supports.

Motor control research has historically treated aggregated findings from small homogeneous samples as revealing universal principles (8). This paradigm has contributed to poor replication rates and limited clinical translation (9). As a field, we can do better. Reviewers and editors play a crucial role by requiring adequate sample characterization and attention to individual differences before accepting claims about universal mechanisms.

I encourage Kim et al. (1) to revise their excellent conceptual framework with empirical work that matches its ambition—work that takes both population diversity and brain diversity seriously.

DISCLAIMERS

The content and any opinions expressed in this article are those of the authors and do not necessarily represent the views of the American Physiological Society.

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REFERENCES

1. **Kim JJ**, **Shankar VR**, **Delmas S**, **Choi YJ**, **Weintraub M**, **Malik RJ**, **Yacoubi B**, **Christou EA.** Distinct effects of visual gain manipulation on force variability and smoothness during constant isometric contractions. *J Neurophysiol*. 135: 324–333, 2026. doi:10.1152/jn.00391.2025.
2. **Henrich J**, **Heine SJ**, **Norenzayan A.** The weirdest people in the world? *Behav Brain Sci* 33: 61–83, 2010. doi:10.1017/S0140525X0999152X.
3. **Chiao JY**, **Cheon BK.** The weirdest brains in the world. *Behav Brain Sci* 33: 88–90, 2010. doi:10.1017/S0140525X10000282.
4. **Marek S**, **Tervo-Clemmens B**, **Calabro FJ**, **Montez DF**, **Kay BP**, **Hatoum AS**, **et al.** Reproducible brain-wide association studies require thousands of individuals. *Nature* 603: 654–660, 2022 [Erratum in *Nature* 605: E11, 2022]. doi:10.1038/s41586-022-04492-9.
5. **Falk EB**, **Hyde LW**, **Mitchell C**, **Faul J**, **Gonzalez R**, **Heitzeg MM**, **Keating DP**, **Langa KM**, **Martz ME**, **Maslowsky J**, **Morrison FJ**, **Noll DC**, **Patrick ME**, **Pfeffer FT**, **Reuter-Lorenz PA**, **Thomason ME**, **Davis-Kean P**, **Monk CS**, **Schulenberg J.** What is a representative brain? Neuroscience meets population science. *Proc Natl Acad Sci USA* 110: 17615–17622, 2013. doi:10.1073/pnas.1310134110.
6. **Fisher AJ**, **Medaglia JD**, **Jeronimus BF.** Lack of group-to-individual generalizability is a threat to human subjects research. *Proc Natl Acad Sci USA* 115: E6106–E6115, 2018. doi:10.1073/pnas.1711978115.
7. **Molenaar PCM.** A manifesto on psychology as idiographic science: bringing the person back into scientific psychology, this time forever. *Measurement* 2: 201–218, 2004. doi:10.1207/s15366359mea0204_1.
8. **Button KS**, **Ioannidis JPA**, **Mokrysz C**, **Nosek BA**, **Flint J**, **Robinson ESJ**, **Munafò MR.** Power failure: why small sample size undermines the reliability of neuroscience. *Nat Rev Neurosci* 14: 365–376, 2013 [Erratum in *Nat Rev Neurosci* 14: 451, 2013]. doi:10.1038/nrn3475.
9. **Open Science Collaboration.** Estimating the reproducibility of psychological science. *Science* 349: aac4716, 2015. doi:10.1126/science.aac4716.