Signing up to motor signatures: a unique link to action

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EDITORIAL FOCUS

Signing up to motor signatures: a unique link to action

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We increasingly interact with the world via links that are unique to us. So we hear more about personalized medicine, personalized advertising, personalized training, and more. Such links are becoming more sophisticated and widespread in their use. They range from our fingerprints, our facial and iris images, our electrocardiogram (8), and of course our DNA (Fig. 1*A*). What about recognition based on our patterns of motion? We can recognize individuals from their gait—do they limp? Are their hip movements symmetrical? Not surprisingly, algorithms can detect individuals from the forces and movements they generate while walking (e.g., 3), forces and movements that must result from patterns of activity in groups of muscles. More than three decades ago we had reports that individuals differ in leg muscle activity in common tasks (1, 9). What was unclear was whether these differences were associated with muscle activation patterns unique to each individual, another personalized biometric link.

In a paper published in this issue of the *Journal of Applied Physiology*, Hug and colleagues (4) have explored the capacity of a machine learning approach (using support vector machine analysis) to identify individuals from a group of 80 based on the patterns of electromyographic activity (EMG) of eight muscles in one leg. Their approach, which relied on the temporal pattern of surface EMGs rather than their magnitude, was applied equally successfully to walking on a treadmill at 1.1 m/s or pedaling on a cycle ergometer at different power outputs (up to 150 W and up to 15% maximum; 80 rpm). A schematic representation of the approach is shown in Fig. 1*B*. The chosen tasks—walking and cycling—are of interest as walking is arguably a more innate task than cycling (10), although both are likely to access a similar set of motor "modules" (2, 5). While considerable attention was given to controlling the motor tasks, the surface EMG electrodes were placed in standard locations and their position was not marked. Of the 80 participants, 53 returned for a second study.

To recognize an individual from data collected in one session, it was not necessary to use EMG activity from all eight muscles; cyclic activity in only three muscles gave ~90% recognition in both pedaling and walking. Remarkably, the algorithm was almost as accurate at recognizing individuals when they repeated the pedaling and walking a couple of weeks later. Here activity in six muscles gave accurate recognition in >80% of EMG cycles. In this way, muscle activation patterns were unique motor signatures.

The work leaves unanswered some basic questions: what does it mean when some combinations of muscles perform better than others? Compared with EMG patterns, how well does this form of machine learning perform when applied to task kinetics and kinematics? Would such kinetic and kinematic signatures be linked to motor signatures? What can be learned from cycles that could not be correctly identified? Although there must be a nexus between profiles of muscle activity and the forces needed to generate body motion, there is an envelope of solutions that allows for the individuality highlighted here. Having said this, at what stage do our motor patterns become unique? How distinct are motor patterns identifiable in newborns, and how do they develop over time and change based on the changing mechanics of the limbs and characteristics of their muscles (e.g., 6)?

Finally, your signature's idiosyncratic form is instantly recognizable whether it is written with a pen on paper, with a stylus on a tablet, or a brush on a billboard. This level of uniqueness transcends even motor signatures of the type described by Hug and colleagues (4)—it represents a truly advanced level of motor programming and personalization (7). Thus there remains much to learn about the generation, development, and malleability of motor "programs" from their high-level selection right down to the motoneuronal output to the muscles and the limits imposed by mechanical constraints.

It is interesting to speculate about the impact of measuring the uniqueness of muscle patterns in clinical and rehabilitation settings—here the concept of individual signatures and the new methods to measure them may be useful in identification and treatment of pathological locomotor patterns.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

S.C.G., S.M., and M.H. drafted manuscript; S.C.G., S.M., and M.H. edited and revised manuscript; S.C.G., S.M., and M.H. approved final version of manuscript.

REFERENCES

1. **Arsenault AB, Winter DA, Marteniuk RG.** Is there a 'normal' profile of EMG activity in gait? *Med Biol Eng Comput* 24: 337–343, 1986. doi:10.1007/BF02442685.
2. **Barroso FO, Torricelli D, Moreno JC, Taylor J, Gomez-Soriano J, Bravo-Esteban E, Piazza S, Santos C, Pons JL.** Shared muscle synergies in human walking and cycling. *J Neurophysiol* 112: 1984–1998, 2014. doi:10.1152/jn.00220.2014.

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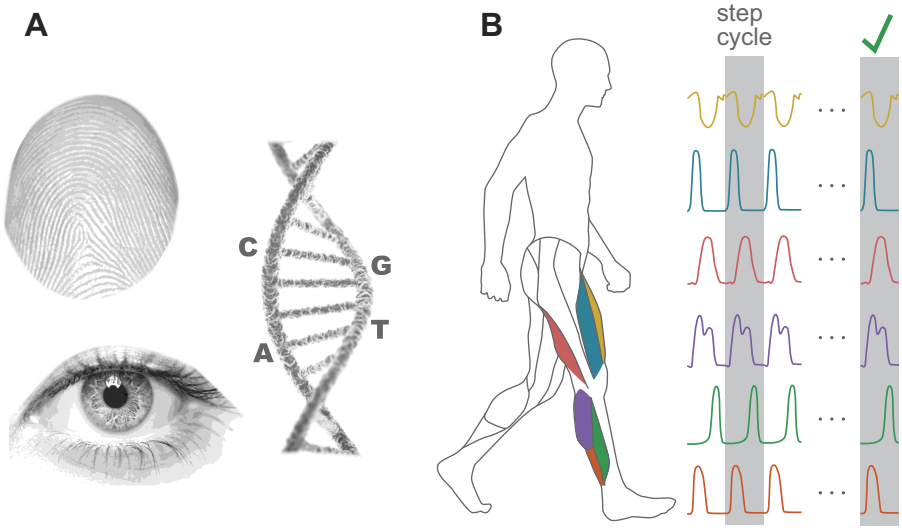

Fig. 1. *A*: depicts three ways by which a person can be recognized: fingerprint, iris scan, and genome sequencing. *B*: shows schematically the procedure used by Hug and colleagues (4). Cyclic EMGs were recorded from leg muscles during walking on a treadmill. The algorithm (based on support vector machine analysis) was able to match successfully the "signature" of EMGs from one step cycle with those of an individual participant.

3. **Horst F, Mildner M, Schöllhorn WI.** One-year persistence of individual gait patterns identified in a follow-up study - A call for individualised diagnose and therapy. *Gait Posture* 58: 476–480, 2017. doi:10.1016/j.gaitpost.2017.09.003.
4. **Hug F, Vogel C, Tucker K, Dorel S, Deschamps T, Le Carpentier E, Lacourpaille L.** Individuals have unique muscle activation signatures as revealed during gait and pedaling. *J Appl Physiol (1985)* 127: 1165–1174, 2019. doi:10.1152/japplphysiol.01101.2018.
5. **Lacquaniti F, Ivanenko YP, Zago M.** Patterned control of human locomotion. *J Physiol* 590: 2189–2199, 2012. doi:10.1113/jphysiol.2011.215137.
6. **Lacquaniti F, Ivanenko YP, Zago M.** Development of human locomotion. *Curr Opin Neurobiol* 22: 822–828, 2012. doi:10.1016/j.conb.2012.03.012.
7. **Merton PA.** How we control the contraction of our muscles. *Sci Am* 226: 30–37, 1972. doi:10.1038/scientificamerican0572-30.
8. **Odinaka I, Lai P, Kaplan AD, O'Sullivan JA, Sirevaag EJ, Rohrbaugh JW.** ECG biometric recognition: a comparative analysis. *IEEE Trans Inf Foren Sec* 7: 1812–1824, 2012. doi:10.1109/TIFS.2012.2215324.
9. **Pedotti A.** A study of motor coordination and neuromuscular activities in human locomotion. *Biol Cybern* 26: 53–62, 1977. doi:10.1007/BF00363992.
10. **Srinivasan M, Ruina A.** Computer optimization of a minimal biped model discovers walking and running. *Nature* 439: 72–75, 2006. doi:10.1038/nature04113.