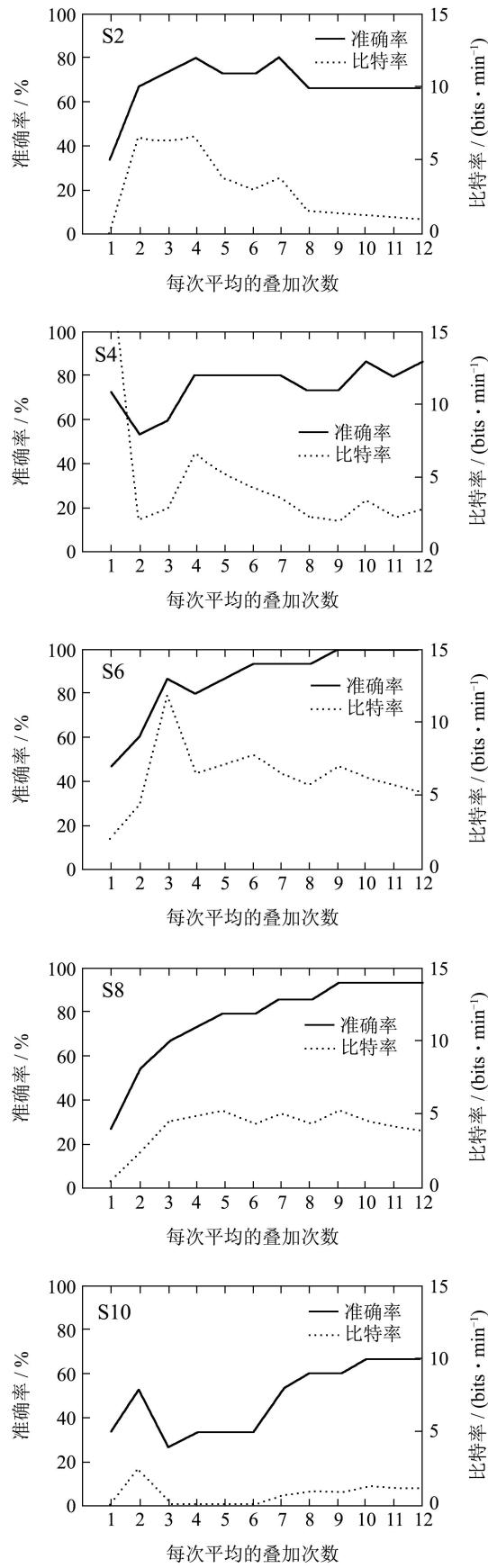
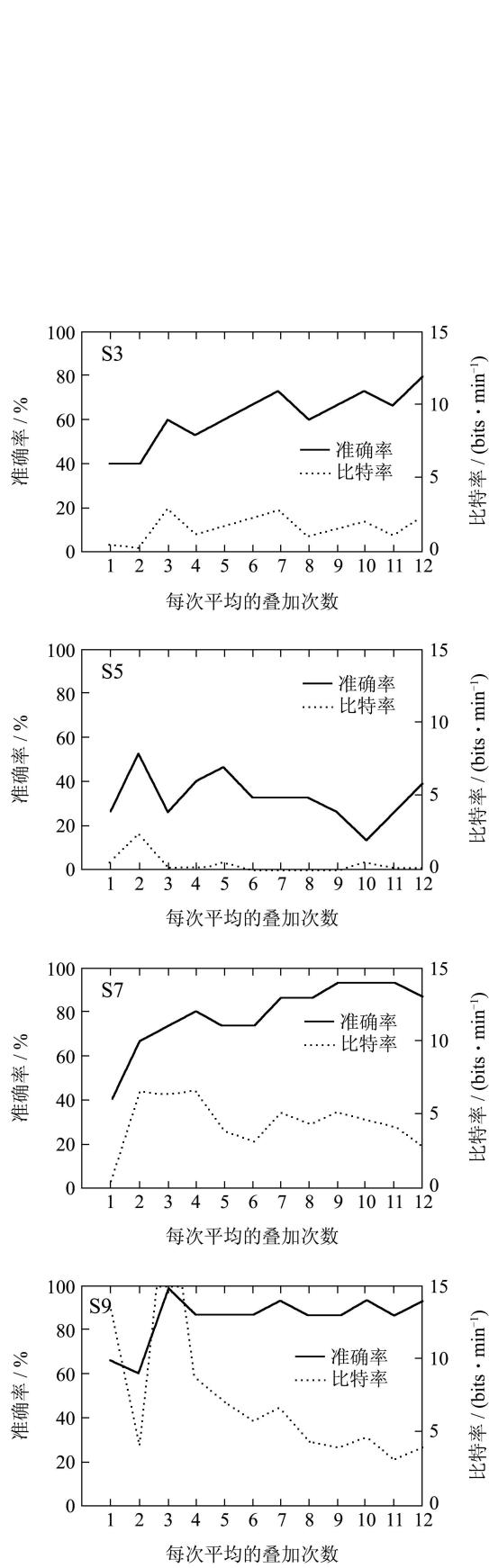


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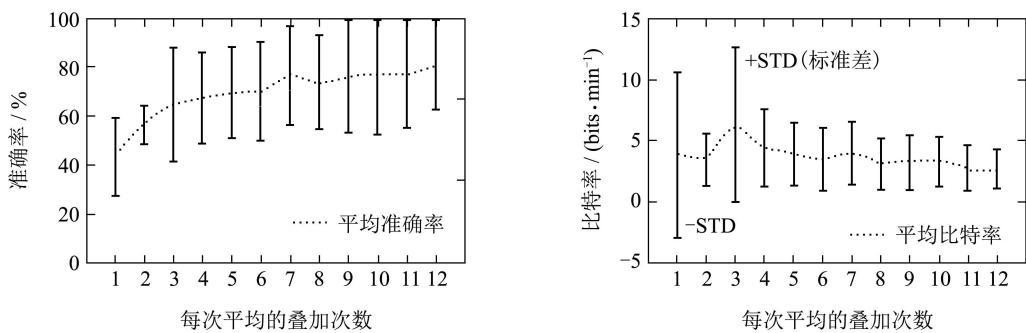


Fig. 8 The classification accuracy and bit rate of 10 subjects

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表1 在线叠加次数、准确率及比特率

Table 1 The trials for average, classification accuracy and bit rate of online experiment

| Á | þ U\ ê | O(Ç /%) | A Ç /(bits · min⁻¹) |
|-------|--------|-----------|---------------------|
| S1 | 6.4 | 100 | 9.9 |
| S2 | 6.3 | 60 | 1.4 |
| S3 | 5.3 | 100 | 12.0 |
| S4 | 5.9 | 80 | 4.5 |
| S5 | 6.8 | 50 | 0.5 |
| S6 | 5.3 | 100 | 12.0 |
| S7 | 4.1 | 70 | 3.9 |
| S8 | 4.2 | 70 | 3.8 |
| S9 | 4.1 | 60 | 2.1 |
| S10 | 4.7 | 60 | 1.8 |
| o þ Š | 5.38 | 1.0 | 75.19 |
| | | | 5.24.4 |

5.3.2.2. Conclusion (Discussion and conclusion)

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6. References (References):

- [1] VAN GERVERN M, WANG M, FARQUHAR J, et al. The brain-computer interface cycle [J]. *Journal of Neural Engineering*, 2009, 6(4): 1771 – 1779.
- [2] ZHOU Z, YIN E, LIU Y, et al. A novel task-oriented optimal design for P300-based brain-computer interfaces [J]. *Journal of Neural Engineering*, 2014, 11(5): 1 – 9.
- [3] WOLPAW J R, BIRBAUMER N, MCFARLAND D J, et al. Brain-computer interfaces for communication and control [J]. *Clinical Neurophysiology*, 2002, 113(6): 767 – 791.
- [4] JIN J, DALY I, ZHANG Y, et al. An optimized ERP brain-computer interface based on facial expression changes [J]. *Journal of Neural Engineering*, 2014, 11(3): 1082 – 1088.
- [5] BRUNNER P, JOSHI S, BRISKIN S, et al. Does the P300 speller depend on eye gaze [J]. *Journal of Neural Engineering*, 2010, 7(5): 1 – 9.
- [6] HOHNE J, SCHREUDER M, BLANKERTZ B, et al. A novel 9-class auditory ERP paradigm driving a predictive text entry system [J]. *Frontiers in Neuroscience*, 2011, 99(5): 1 – 10.
- [7] SCHREUDER M, BLANKERTZ B, TANGERMAN M. A new auditory multi-class brain-computer interface paradigm: spatial hearing as an informative cue [J]. *PLoS ONE*, 2010, 5(4): 1 – 14.
- [8] KAUFMANN T, HOLZ E M, K ÜBLER A. Comparison of tactile, auditory, and visual modality for brain-computer interface use: a case study with a patient in the locked-in state [J]. *Frontiers in Neuroscience*, 2013, 7(129): 1 – 12.

- [9] FURDEA A, HALDER S, KRUSIENSKI D J, et al. An auditory odd-ball (P300) spelling system for brain-computer interfaces [J]. *Biophysiology*, 2009, 46(3): 617 – 625.
- [10] Ç > , € 煙, Ü ê I , . Ä u P300 #. BCI¥ © Ñ \ J [... X Ú [J]. > f AE , 2009, 37(8): 1733 – 1738. (WU Bian, SU Yu, ZHANG Jianhui, et al. A virtual chinese keyboard BCI system based on P300 potentials [J]. *Acta Electronica Sinica*, 2009, 37(8): 1733 – 1738.)
- [11] XU N, GAO X R, HONG B, et al. BCI competition 2003-data set IIb: enhancing P300 wave detection using ICA-based subspace projections for BCI applications [J]. *IEEE Transactions on Biomedical Engineering*, 2004, 51(6): 1067 – 1072.
- [12] ö 7 , q ä ü . Ä u - ‡ ' é > M Å • > Ä € > É Ú X Ú [J]. > n Ø † A ^ , 2012, 29(11): 1507 – 1511. (WANG Hongtao, ZOU Heliang. Asynchronous TV remote control system based on event-related potential brain-computer interface [J]. *Control Theory & Applications*, 2012, 29(11): 1507 – 1511.)
- [13] Ü ý A , H p , š O. Ä u BCI e € 9 ī x E X Ú i Ä [J]. É 2 > f %E OEAEAE , 2013, 33(1): 36 – 39. (ZHANG Yanna, GUO Kai, KONG Wanzen. Research and development of auxiliary rehabilitation system for lower limbs based on BCI [J]. *Journal of Hangzhou Dianzi University*, 2013, 33(1): 36 – 39.)
- [14] H Z u , 2 . • Ä Ä å AE . š £ Ä Ä i < \$ Ä 5 y [J]. > n Ø † A ^ , 2004, 21(3): 443 – 446. (GUO Binghua, HU Yueming. Motion planning for nonholonomic robot with dynamic modeling [J]. *Control Theory & Applications*, 2004, 21(3): 443 – 446.)
- [15] LI Y, PAN J, WANG F, et al. A hybrid BCI system combining P300 and SSVEP and its application to wheelchair control [J]. *IEEE Transactions on Biomedical Engineering*, 2013, 60(11): 3156 – 3166.
- [16] LONG J, LI Y, WANG H, et al. A hybrid brain computer interface to control the direction and speed of a simulated or real wheelchair [J]. *IEEE Transactions on Neural Systems & Rehabilitation Engineering A Publication of the IEEE Engineering in Medicine & Biology Society*, 2012, 20(5): 720 – 729.
- [17] ī u , ‡ , o ö Ç , . † M > Ä i < • E å [J]. g Ä z AE , 2012, 38(8): 1229 – 1246. (FU Yunfa, WANG Yuechao, LI Hongyi, et al. Direct brain-controlled robot interface technology [J]. *Acta Automatica Sinica*, 2012, 38(8): 1229 – 1246.)
- [18] " " Ä , o ? , x ° Ö , . ~ « Ä u SSVEP • < Ä i < É Ú M Å • > , X Ú [J]. Ä i < , 2011, 33(2): 129 – 135. (DENG Zhidong, LI Xiuquan, ZHENG Kuanhao, et al. A humanoid robot control system with SSVEP-based asynchronous brain-computer interface [J]. *Robot*, 2011, 33(2): 129 – 135.)
- [19] o + ° , ¶ 脣, y %, . M-Å • 3 £ Ä > , ¥ A^ i Ä ? Đ [J].) Ô š AEó § AE, " , 2011, 28(3): 613 – 617. (LI Penghai, DING Hao, WAN Baikun, et al. Research progress on application of brain-computer-interface in mobile peripheral Control [J]. *Journal of Biomedical Engineering*, 2011, 28(3): 613 – 617.)
- [20] LI J, LIANG J, ZHAO Q, et al. Design of assistive wheelchair system directly steered by human thoughts [J]. *International Journal of Neural Systems*, 2013, 23(3): 1001 – 1007.
- [21] 4 Y , o ~ , ö 7 , . Ä u ‡ (Ä D a i M > Ö « ; æ X Ú i Ä [J]. O Ž Ä y b † , , 2012, 20(9): 2393 – 2395. (LIU Tian, LI Yuanqing, WANG Hongtao, et al. Research of brain-controlled wheelchair obstacle avoidance system based on ultrasonic [J]. E-mail: beiwang@ecust.edu.cn.)
- sensor [J]. *Computer Measurement & Control*, 2012, 20(9): 2393 – 2395.)
- [22] BIRBAUMER N, GHANAYIM N, HINTERBERGER T, et al. A spelling device for the paralysed [J]. *Nature*, 1999, 398(6725): 297 – 298.
- [23] PFURTSCHELLER G, MÜLLER G R, PFURTSCHELLER J, et al. "Thought"-control of functional electrical stimulation to restore hand grasp in a patient with tetraplegia [J]. *Neuroscience Letters*, 2003, 351(1): 33 – 36.
- [24] VIDAL J J. Toward direct brain-computer communication [J]. *Annual review of Biophysics and Bioengineering*, 1973, 2(1): 157 – 180.
- [25] FARWELL L A, DONCHIN E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials [J]. *Electroencephalography and Clinical Neurophysiology*, 1988, 70(6): 510 – 523.
- [26] HILL N, LAL T, BIERIG K, et al. An auditory paradigm for brain-computer interfaces [J]. *Advances in Neural Information Processing Systems*, 2004, 17(1): 569 – 576.
- [27] SELLERS E W, DONCHIN E. A P300-based brain-computer interface: initial tests by ALS patients [J]. *Clinical Neurophysiology*, 2006, 117(3): 538 – 548.
- [28] 1 y , 7- , Ü %, . M > : Ä u M-Å • < Ä K Ü , > [J]. g Ä z AE , 2013, 39(3): 208 – 221. (WANG Xingyu, JIN Jing, ZHANG Yu, et al. Brain control: human-computer integration control based on brain-computer interface [J]. *Acta Automatica Sinica*, 2013, 39(3): 208 – 221.)
- [29] ZHANG Y, ZHOU G, ZHAO Q, et al. Spatial-temporal discriminant analysis for ERP-based brain-computer interface [J]. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 2013, 21(2): 233 – 243.
- [30] JIN J, ALLISON B Z, BRUNNER C, et al. P300 chinese input system based on Bayesian LDA [J]. *Biomedizinische Technik*, 2010, 55(1): 5 – 18.
- [31] JIN J, ALLISON B Z, SELLERS E W, et al. An adaptive P300-based control system [J]. *Journal of Neural Engineering*, 2011, 8(3): 292 – 301.

作者简介:

王 xywang (1944-), 女, 汉族, 博士, 教授, 主要研究方向为脑机接口技术。E-mail: xywang@ecust.edu.cn;

李 jinjing (1991-), 男, 汉族, 硕士研究生, 主要研究方向为脑机接口技术。E-mail: 1083659486@qq.com;

王 zhong (1981-), 男, 汉族, 硕士研究生, 主要研究方向为脑机接口技术。E-mail: jinjing@ecust.edu.cn;

张 zhangyu (1986-), 男, 汉族, 硕士研究生, 主要研究方向为脑机接口技术。E-mail: zhangyu0112@gmail.com;

王 beiwang (1976-), 男, 汉族, 硕士研究生, 主要研究方向为脑机接口技术。E-mail: beiwang@ecust.edu.cn。