Using temporal and spatial features of a reciprocal tapping task to detect sub-maximal effort among non-disabled participants

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BACKGROUND – PARALYMPIC SPORT

- Purpose of classification in Paralympic Sport: to minimize the impact that impairment has on competition outcomes
- Measures of impairment must be valid, reliable and ratio scaled
- Three of eight eligible physical impairments affect coordination
    - Ataxia
    - Athetosis
    - Hypertonia
- Measures of coordination require Maximal Voluntary Effort (MVE) in order to obtain a valid test result

INTENTIONAL MISREPRESENTATION (IM)

- What is IM?: Deliberately exaggerating impairment severity by underperforming on tests of impairment (e.g. tests of strength and coordination) (IPC, 2007)

- Why do athletes do it? Athletes have potential to be allocated to a class for athletes who are more severely impaired, thereby increasing chances of success

- What is the penalty? Punishments available for both athletes/support personnel
- What is the problem? But no established methods of detection so athletes can't be sanctioned

STUDY AIMS

1. To identify spatial and temporal features of a reciprocal tapping task that:
    - Are significantly different between MVE and sub-maximal effort (SME) conditions, and
    - Have a large effect size across three sessions

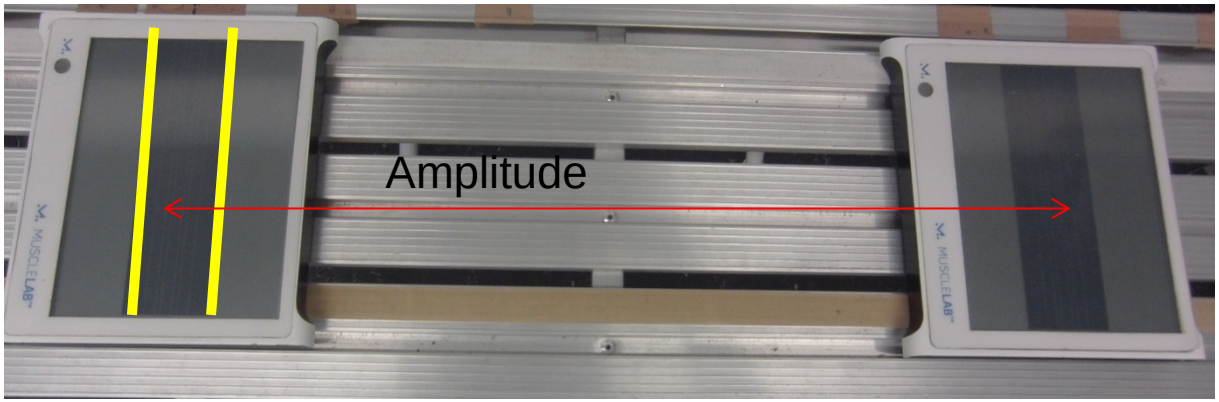
2. To examine whether the features identified in 1. could be combined to detect SME among non-disabled participants, by calculating sensitivity and specificity values

METHODS

- 49 non-disabled participants (20 males, 29 females); Mean age 24 (±3.7) years
- Procedures: each participant completed eight 15 second reciprocal tapping tasks with dominant hand under two conditions:
  - MVE (as fast and as accurately as possible); and
  - SME conditions (speeds ≥ 20% slower than max) on three different testing occasions
- Tasks varied in their indexes of difficulty (IDs)

$$ID = \log_2 (2A/W)$$ (Fitts, 1954)

Where A = amplitude and W = target width

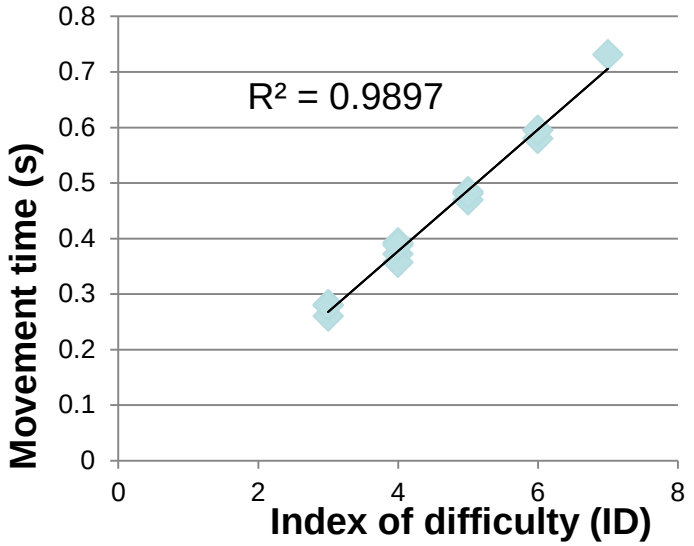


METHODS CONT.

Two other important components of the study design:

1. Participants were thoroughly familiarised with Fitts' law relationship (R^2 score) prior to completing the tapping task in the first session
2. Participants were given an incentive to be the "best cheat" –$100 (first), $50 (second), $25 (third) for the three persons who achieved the highest average R^2 score under SME conditions

Note: To be eligible for these rewards had to be moving at least 20% slower than max for 2 of the 8 IDs completed



Under MVE conditions – "as fast and as accurately as possible")

STATISTICAL METHODS – PHASE 1

- Fourteen features were analysed: five temporal (i.e. R^2 score) and nine spatial features

- Used paired t-tests (with Benjamini Hochberg corrections) and Effect size calculation (Cohen's D) to determine which features could differentiate between MVE and SME

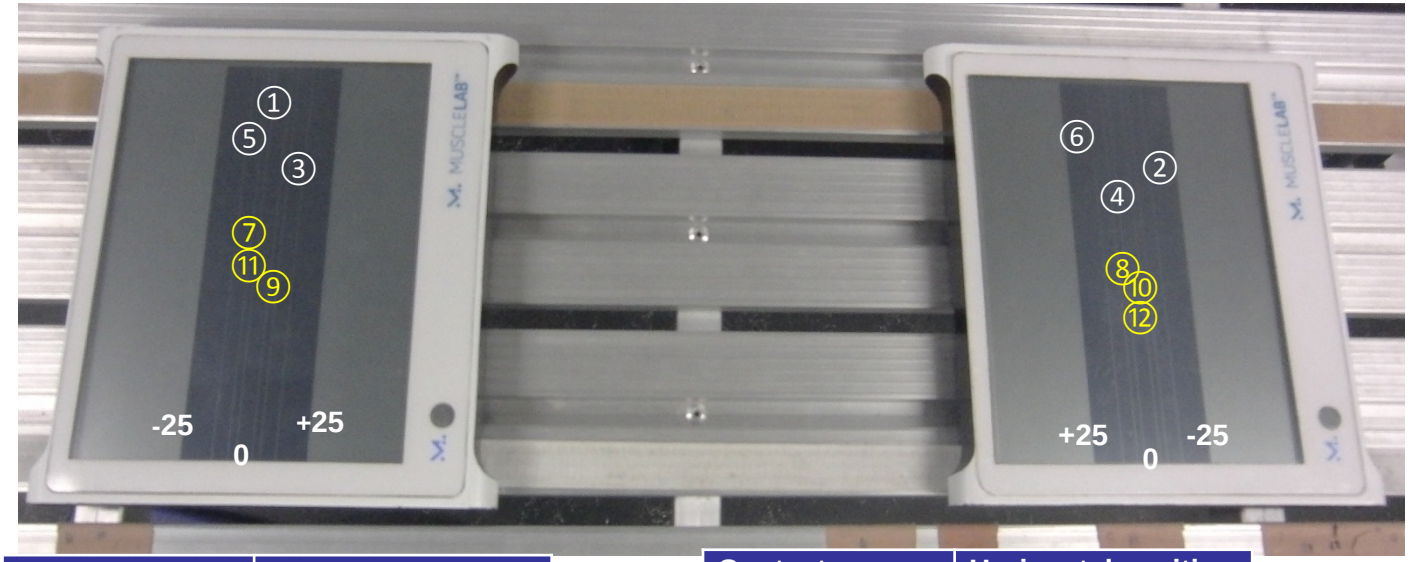
RESULTS – PHASE 1

- Following features had 1. significant differences between MVE and SME conditions ($p<0.05$) and 2. large effect size ($>\pm0.8$) across the three sessions

1. R^2 score (T_1R^2)
2. Accuracy (%) (S_1Acc)
3. Standard deviation of the horizontal contact position (S_3HSD)

Note: All spatial features were based on an average of the eight IDs

HSD CALCULATION



Contact number	Horizontal position (mm)
1	0
2	-20
3	16
4	2
5	-10
6	23
Standard deviation (SD)	HSD =15.9

Contact number	Horizontal position (mm)
7	-2
8	3
9	4
10	0
11	-2
12	1
Standard deviation (SD)	HSD = 2.5

RESULTS – PHASE 1

- Following features had 1. significant differences between MVE and IM conditions ($p<0.05$) and 2. large effect size ($>\pm0.8$) across the three sessions

1. R^2 score (T_1R^2)
2. Accuracy (S_1Acc) (%)
3. Standard deviation of the horizontal contact position (S_3HSD) (mm)
4. Coefficient of variation of the horizontal movement amplitude (%) (S_6CVHamp)
5. Coefficient of variation of the absolute movement amplitude (%) (S_8CVAbamp)

Note: All spatial features were based on an average of the eight IDs

STATISTICAL METHODS – PHASE 2

- Checked features for multi-collinearity using correlation matrix, variation inflation factors and tolerance values
- Principle components analysis was performed on those features which were highly correlated with each other ($r>0.8$)
- Four spatial features – S_1Acc, S_3HSD, S_6CVHAmp and S_8AbAmp found to be highly correlated with each other – combined into one component
- Logistic regression analysis was performed – sensitivity and specificity values for various cut-off values were examined using Reciever Operating Characteristic (ROC) curve analysis

RESULTS – LOGISTIC REGRESSION ANALYSIS

- Logistic regression analysis performed for each session using two independent variables: T_1R^2 and spatial component

Independent variable	B	S.E.	Wald	Sig.	Exp (B)
Session 1					
$T1R^2$	-13.538	4.917	7.581	0.006	<0.001
Component 1_session1	-4.195	1.283	10.686	0.001	0.015
Constant	10.897	4.146	6.909	0.009	
Session 2					
T_1R^2	-8.162	4.118	3.930	0.047	<0.001
Component1 _session2	-4.543	1.304	12.140	<0.001	0.011
Constant	6.932	3.571	3.769	0.052	
Session 3					
T_1R^2	-18.646	6.493	8.247	0.004	<0.001
Component1_session 3	-4.297	1.287	11.148	0.001	0.014
Constant	15.491	5.538	7.824	0.005	

ROC CURVE ANALYSIS

Sensitivity, Specificity and Overall Error Rate for Various Cut-off Values of the Model generated by combining T_1R^2 with spatial component (combining four spatial features: S_1Acc, S_3HSD, S_6CVHamp, S_8CVAbamp)											
Cut-off Value	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
Session 1											
Sensitivity (%)	100.00	98.00	98.00	98.00	96.00	96.00	94.00	92.00	85.00	81.00	0.00
Specificity (%)	0.00	79.00	88.00	94.00	96.00	98.00	98.00	98.00	100.00	100.00	100.00
Overall error rate (%)	100.00	23.00	14.00	8.00	8.00	6.00	8.00	10.00	15.00	19.00	100.00
Session 2											
Sensitivity (%)	100.00	98.00	96.00	94.00	92.00	90.00	90.00	90.00	88.00	81.00	0.00
Specificity (%)	0.00	77.00	81.00	85.00	92.00	98.00	98.00	100.00	100.00	100.00	100.00
Overall error rate (%)	100.00	25.00	23.00	21.00	16.00	12.00	12.00	10.00	12.00	19.00	100.00
Session 3											
Sensitivity (%)	100.00	98.00	98.00	98.00	96.00	94.00	94.00	92.00	85.00	79.00	0.00
Specificity (%)	0.00	79.00	85.00	94.00	96.00	96.00	98.00	98.00	98.00	98.00	100.00
Overall error rate (%)	100.00	23.00	17.00	8.00	8.00	10.00	8.00	10.00	17.00	23.00	100.00

DISCUSSION AND CONCLUSIONS

- One temporal (T_1R^2) and four spatial features (S_1Acc, S_3HSD, S_6CVHamp, S_8CVAbamp) appear to have the most potential to differentiate between MVE and SME

- Results from ROC curve analysis suggest that this combination of features has reasonable sensitivity for detecting SME among non-disabled participants when specificity is set at 100%

- Results are promising and must now be replicated in athletes with impaired coordination (e.g., Cerebral Palsy) to determine whether method has application for detecting IM in Paralympic Sport

QUESTIONS?