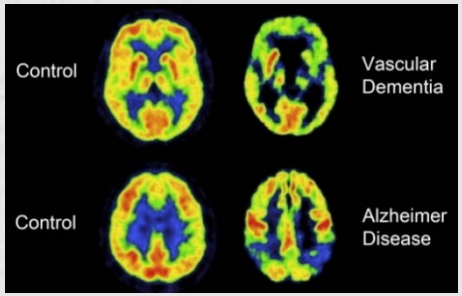
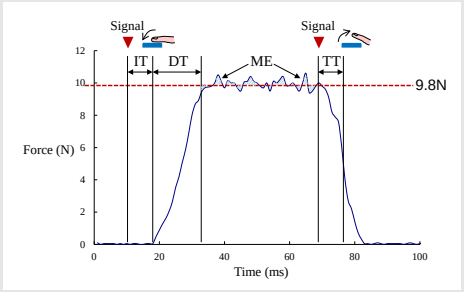
Comparison of Force Control Capabilities (FCCs) in Patients with Motor Intentional Disorders (MIDs) and Normal Controls





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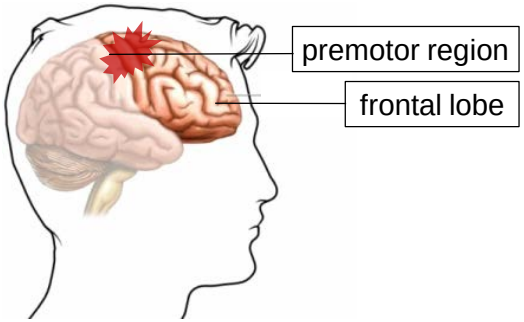
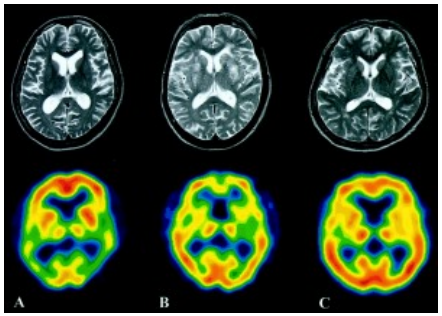
AGENDA

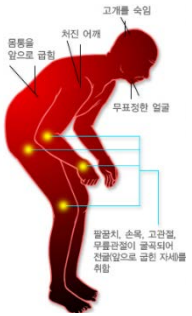
- **Introduction**
  - Background
  - Objective of the Study
- **Research Protocol**
- **Results**
  1) Effects of Age, Gender, and Hand on normal FCCs
  2) Comparison of FCCs bwn. MIDs & Normal Controls
  3) Diagnostic Model for MIDs
- **Discussion**

MIDs: Clinical Significance

- Causes of decrease in motor skills (Holvia et al., 2012; Ward et al., 2003)
  - ✓ Internal factors: age ↑, skeletal muscle mass ↓, muscle strength ↓, cognitive ability ↓
  - ✓ External factor: brain damage
- **Motor intentional disorders (MIDs)**
  - ✓ **Definition**: Motor disorders that disrupt volitional movements (Seo et al., 2009)
  - ✓ **Etiology**: Damage in the premotor region, mainly appeared in brain-damaged patients (e.g., vascular dementia, Parkinson's disease, stroke) (Weintraub, 2008; Hong, 2010)
  - ✓ **Symptom**: **Force control capabilities (FCC) ↓** ➔ motor skills ↓ (Seo et al., 2010)



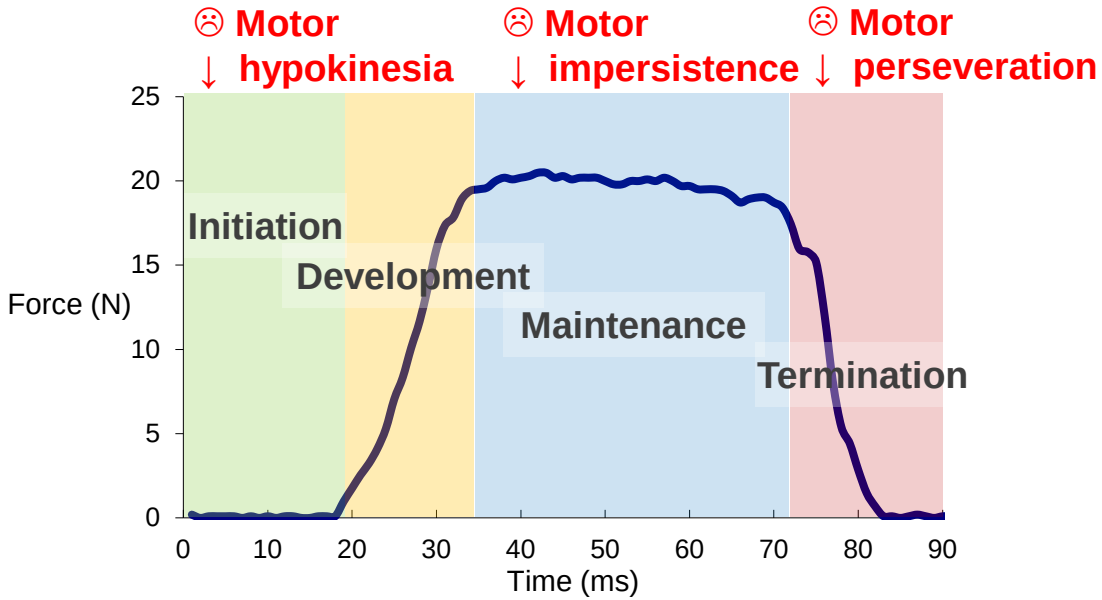




⇒ Important to detect MIDs in the early stage because MIDs are initial symptoms of brain-damaged disorders

Force Control Phases

- **Different types of MID** by force control phase



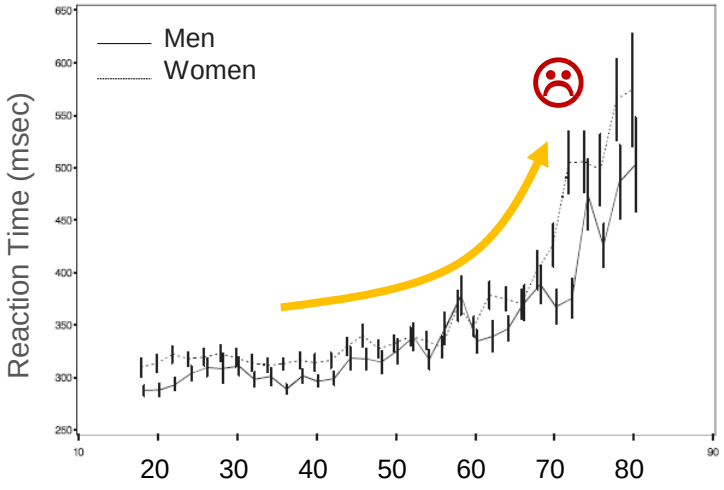
Four phases by force control (Heilman, 2004)

⇒ Existing diagnostic approach: Behavioral observation & bedside test (Crucian et al., 2007)

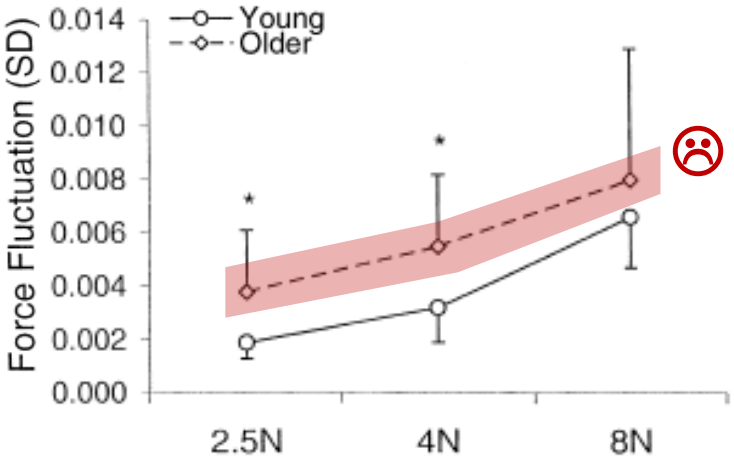
⇒ Need to develop a quantitative system specialized for the diagnosis of MID

Existing Studies on FCC

- Mainly focused on **force initiation and maintenance phases**



Age effect on reaction time
(Der and Deary, 2006)



Age and target force effects
on force fluctuation
(Vinoth et al., 2001)

⇒ Lack of studies on development and termination phases of FCC

⇒ Need to analyze **FCC** according to **four force control phases**

Research Objective

Comparison of Motor Skills

between Patients with MIDs and Normal Controls

by Evaluating Finger Force Control Capabilities (FCCs)

1. **Analysis** of FCCs in normal controls by force control phase
2. **Comparison** of MID patients with normal controls
3. **Development** of a diagnostic model for early screening of MIDs

Research Protocol

S1. System development

- H/W: Finger Touch (FT) system
- S/W: force evaluation interface

S2. Experiment

- Participants: 360 normal controls (20 ~ 70s)
- Evaluation of finger FCCs using FT system

S3. Analysis

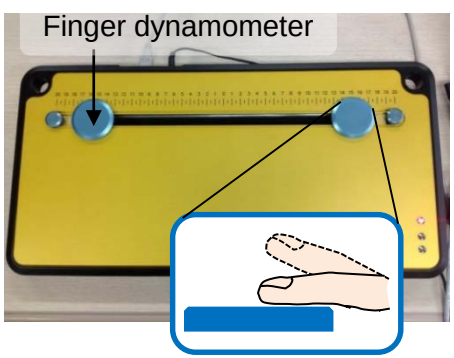
- Age, gender, and hand effects on FCC
- Patients (aMCI, svMCI, SVaD) vs. controls

S4. Diagnostic model development

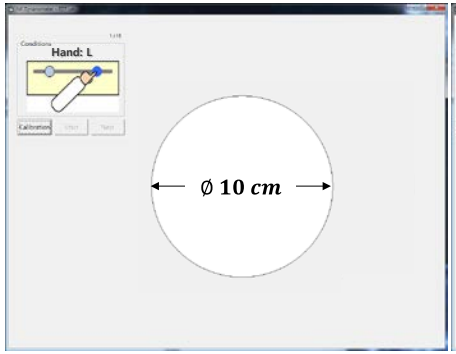
- Binary logistic regression
- ROC-curve analysis

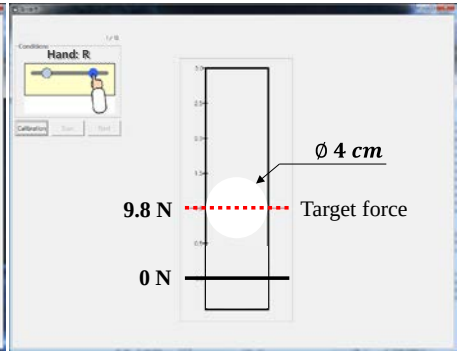
S1. System Development

- **Finger Touch (FT)** (SeedTech Co., South Korea)
  - ✓ Assessment of FCC by force control phase
  - ✓ Two finger dynamometers (load cells) (precision = 0.196 N, sampling rate = 30 ~ 32 Hz)
- 19-inch monitor (FLATRON L1940P, LG Electronics Co., South Korea)
- Evaluation S/W



H/W (FT system & monitor)



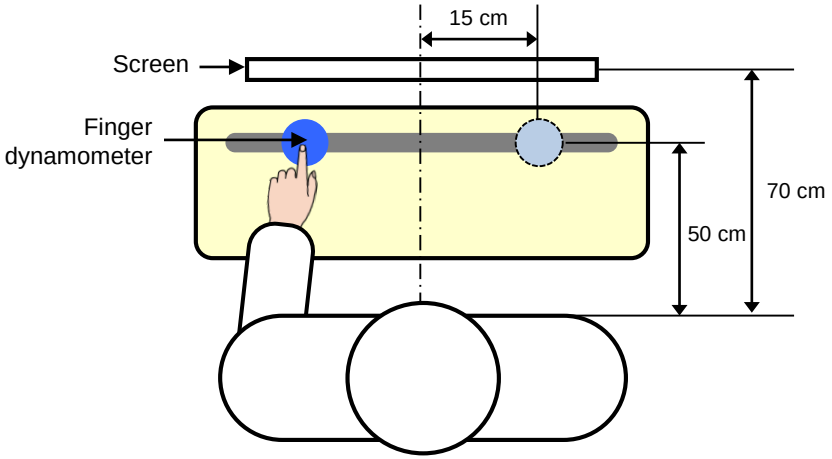


Interface of SW

S2. Experiment: Design

- Participants: 360 **normal controls** (30 males & 30 females from each of age strata 20s to 70s)

- **Three-factor mixed-subjects designs**
  - ✓ Independent variables
    1) **Age** (b-s-f): 20s ~ 70s
    2) **Gender** (b-s-f): male, female
    3) **Hand** (w-s-f): left, right ➔ 8 trials for each hand and force control phase
  - ✓ Dependent variables
    - ➢ Initiation time (**IT**; msec)
    - ➢ Development time (**DT**; msec)
    - ➢ Maintenance error (**ME**; mN)
    - ➢ Termination time (**TT**; msec)

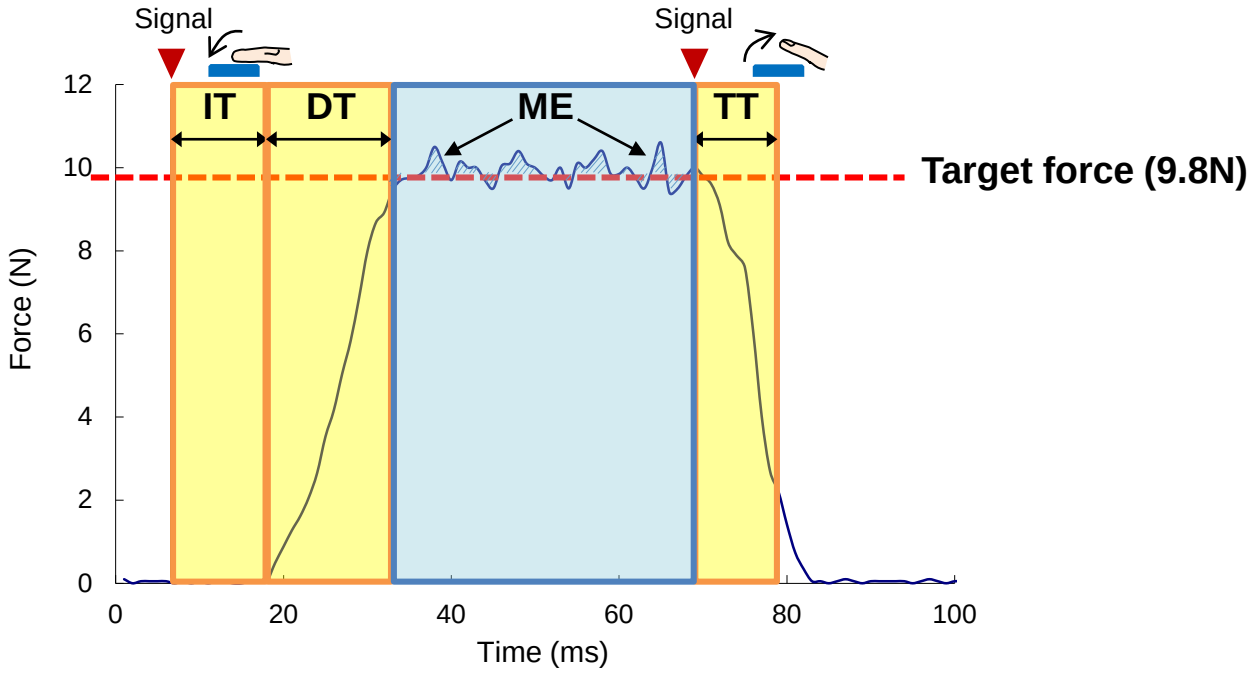


Layout of FT system
(e.g., test condition = left-hand & left-side)

S2. Experiment: Measures

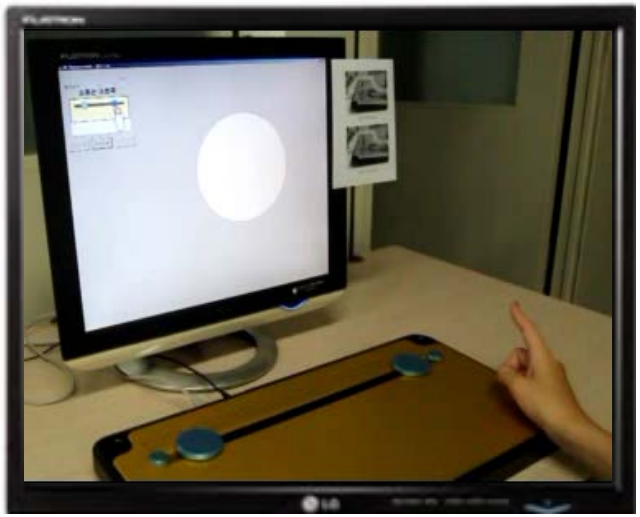
- 4 measures as indicators of motor skills (Seo et al., 2009)
  - ✓ **Speed of movements** (unit: msec)
    - ➢ Initiation time (**IT**)
    - ➢ Development time (**DT**)
    - ➢ Termination time (**TT**)
  - ✓ **Accuracy of movements** (unit: mN)
    - ➢ Maintenance error (**ME**)

➔ **4 tasks**



S2. Experiment: Initiation Phase

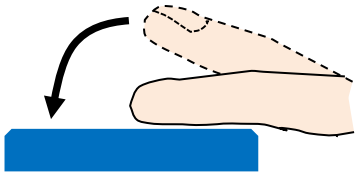
- **IT** (msec): time to press the dynamometer after a visual signal
- **DT** (msec): time to reach to the target force **9.8 N**
- **ME** (mN): average difference between the exerted and target forces
- **TT** (msec): time to release the force from the dynamometer after a visual signal



$$IT = t_j - t_i$$

where, t_i = time to present a visual signal

t_j = time to press the dynamometer



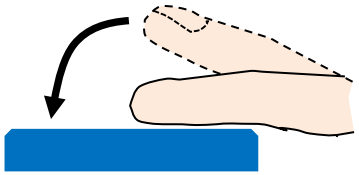
S2. Experiment: Development Phase

- **IT** (msec): reaction time to press the dynamometer after a visual signal
- **DT** (msec): time to reach to the target force 9.8 N
- **ME** (mN): average difference between the exerted and target forces
- **TT** (msec): time to release the force from the dynamometer after a visual signal

$$DT = t_j - t_i$$

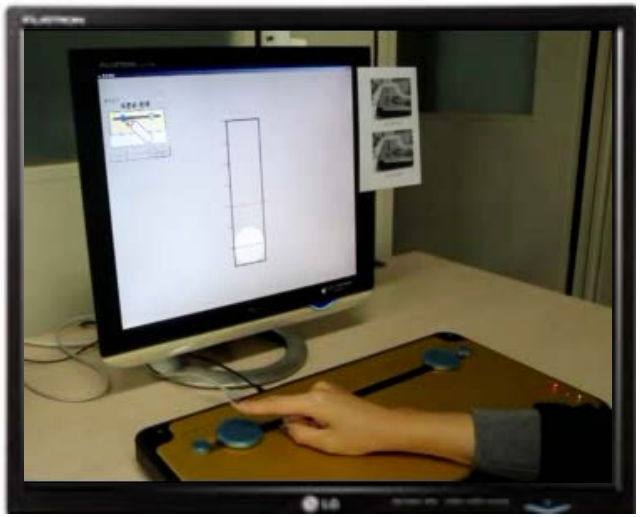
where, t_i = time to press the dynamometer

t_j = time to reach 9.8 N



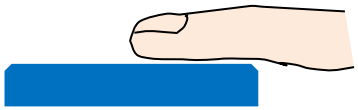
S2. Experiment: Maintenance Phase

- **IT** (msec): reaction time to press the dynamometer after a visual singal
- **DT** (msec): time to reach to the target force **9.8 N**
- **ME** (mN): average difference between the exerted and target forces
- **TT** (msec): time to release the force from the dynamometer after a visual signal



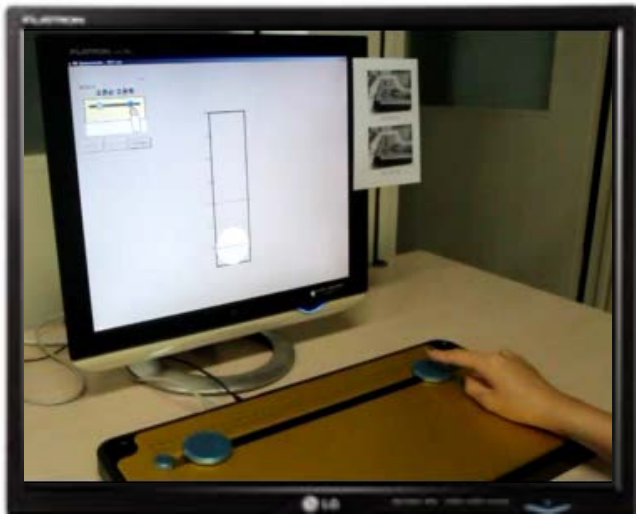
$$ME = \frac{\sum_{i=0}^{10000} |f_i - 9.8\ N|}{10000}$$

where, f_i = finger force at measurement i



S2. Experiment: Termination Phase

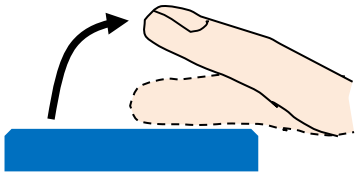
- **IT** (msec): time to press the dynamometer after a visual signal
- **DT** (msec): time to reach to the target force **9.8 N**
- **ME** (mN): average difference between the exerted and target forces
- **TT** (msec): time to release the force from the dynamometer after a visual signal



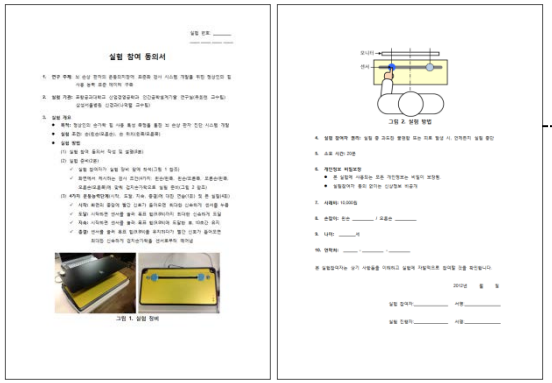
$$TT = t_j - t_i$$

where, t_i = time to present a visual signal

t_j = time to release the force from the dynamometer



S2. Experiment: Procedure



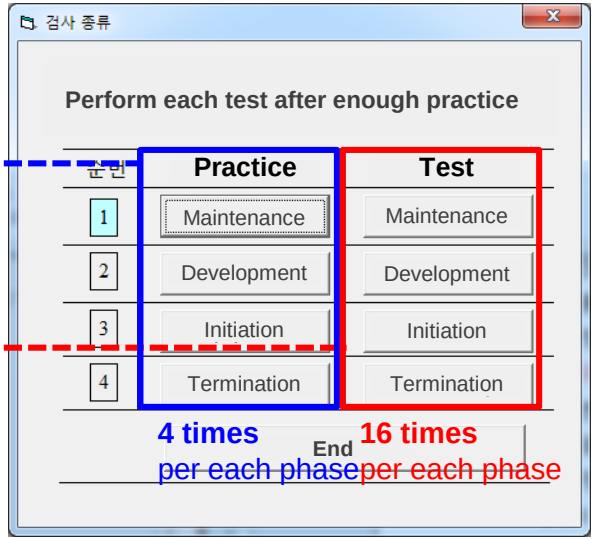
Duration: 20 min.

S1. Preparation
(3 min.)

S2. Practice
(5 min.)

S3. Main experiment
(10 min.)

S4. Debriefing
(2 min.)



※ Tested in random order

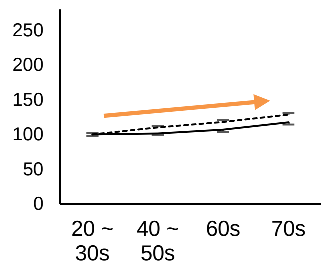
S3. Result: Effects of Age, Gender, Hand on FCCs

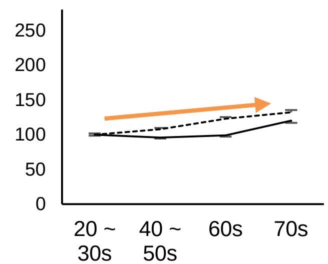
❑ Age, gender, and hand effects on FCCs of normal controls

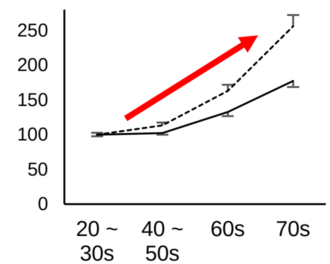
	Initiation time (IT)	Development time (DT)	Maintenance error (ME)	Termination time (TT)
Age (A)	< .001	< .001	< .001	< .001
Gender (G)	.009	.012	< .001	.003
Hand (H)	.803	.008	.644	.032
A × G	< .001	.314	< .001	.379
A × H	.064	.756	.227	.515
G × H	.310	.667	.705	.242
A × G × H	.768	.851	.336	.568

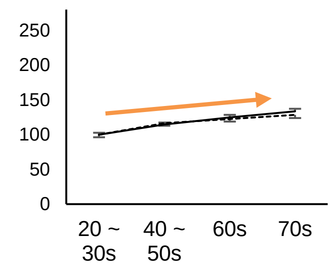
Normalized FCC

—— Male
----- Female









※ Shaded area: $p < .001$

⇒ All phases: **Age ↑ → FCC ↓**

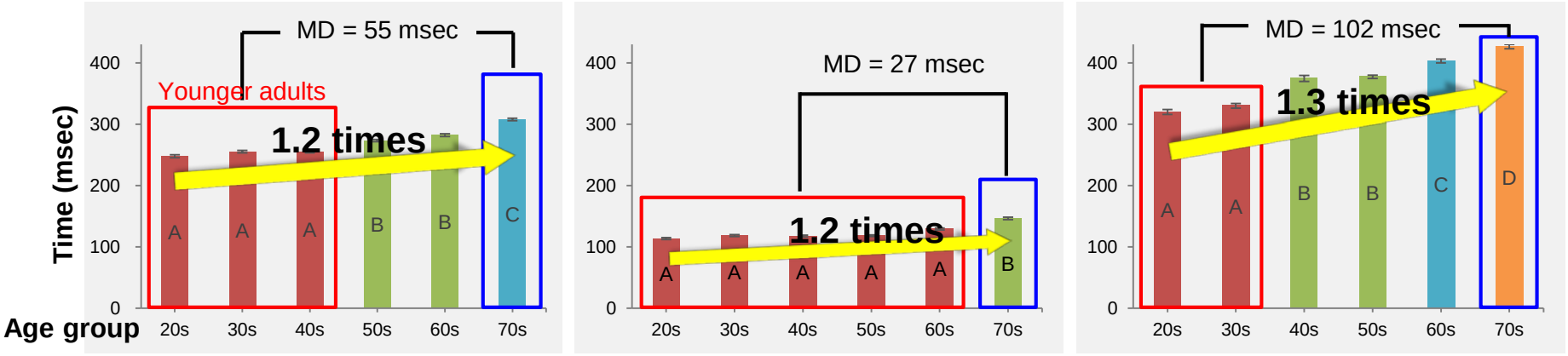
⇒ Degree of motor skill decrease: ME > IT ≈ DT ≈ TT

S3. Result: Speed of Normal Controls

- **Age** effect: age ↑ → IT, DT, TT ↑

  (IT: $F[5, 344] = 18.40$, $p < .001$*; DT: $F[5, 347] = 5.77$, $p < .001$*; TT: $F[5, 341] = 19.08$, $p < .001$*)

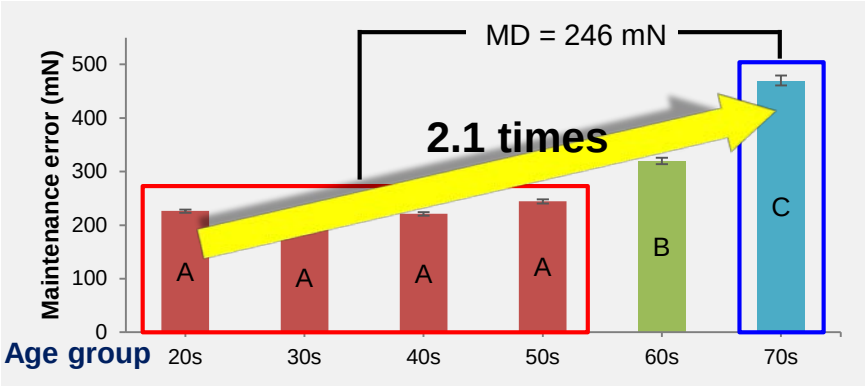
※ MD = mean difference

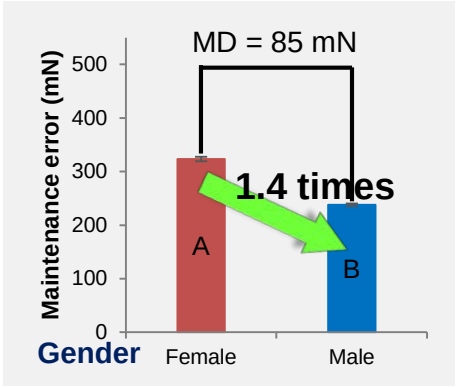


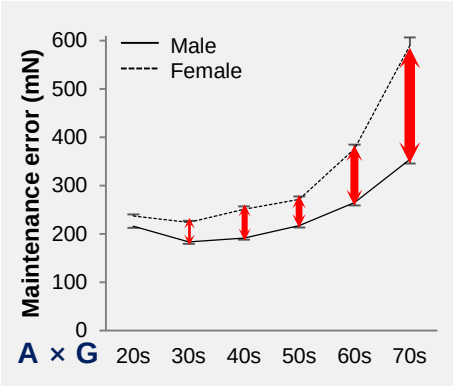
⇒ **IT, DT, and TT of age 70s:** 1.2 ~ 1.3 times ↑ than those of younger adults

S3. Result: Accuracy of Normal Controls

- **Age** effect: age ↑ → ME ↑ (*F*[5, 347] = 47.04, *p* < .001*)
- **Gender** effect: ME of male < ME of female (*F*[1, 347] = 53.03, *p* < .001*)
- **A×G** effect: age ↑ → gender difference of ME ↑ (*F*[5, 347] = 7.18, *p* < .001*)







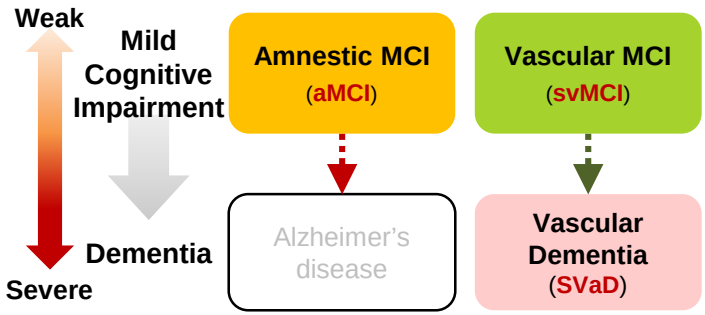
※ MD = mean difference

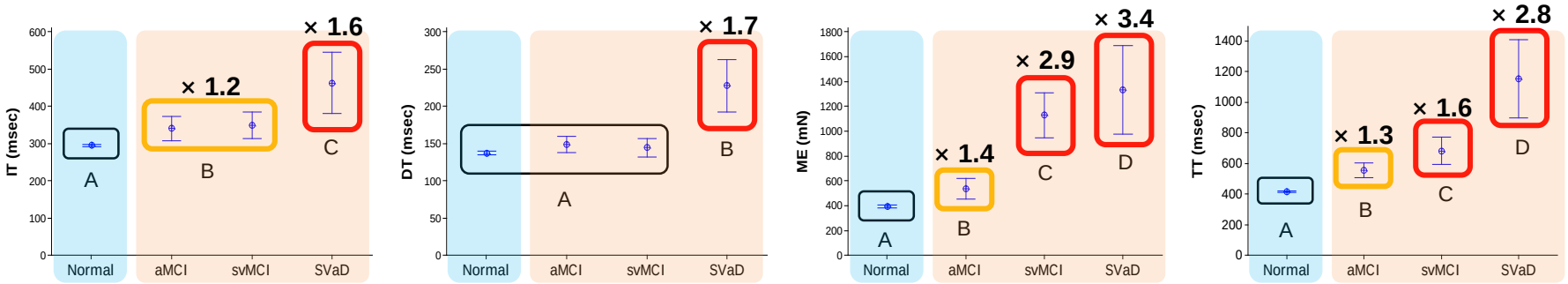
⇒ **ME of 70s**: 2.1 times ↑ than that of 20s ~ 50s

⇒ **ME of female**: 1.4 times ↑ than that of male

S4. Comparison: Patients vs. Controls

- 60s ~ 70s of **normal controls**
- Type of brain-damaged patients (Yoon et al., 2012)
  - ✓ Amnestic MCI (**aMCI**)
  - ✓ Subcortical vascular MCI (**svMCI**)
  - ✓ Subcortical vascular dementia (**SVaD**)





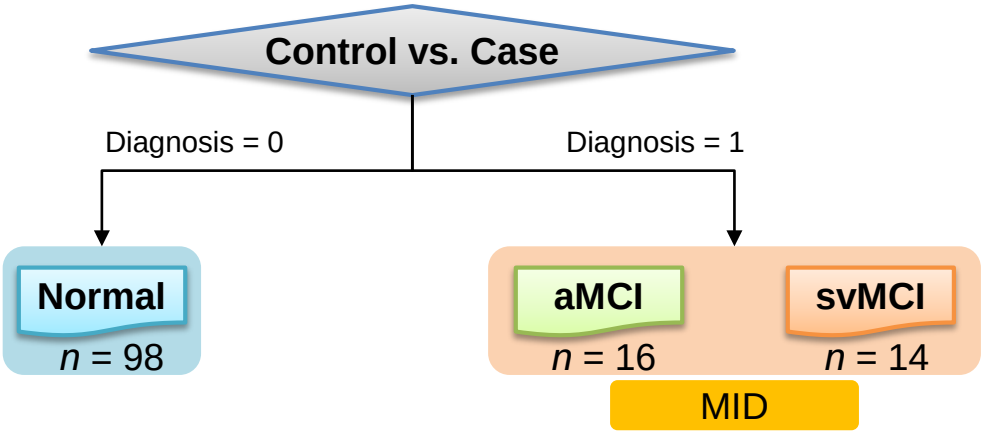
Initiation | Development | Maintenance | Termination

⇒ **FCCs** in all phases: **controls** > **MID patients**

⇒ **Decline** in motor skills: **SVaD** > svMCI > aMCI
(severity ↑) (severity ↓)

S4. Diagnostic Model: Method

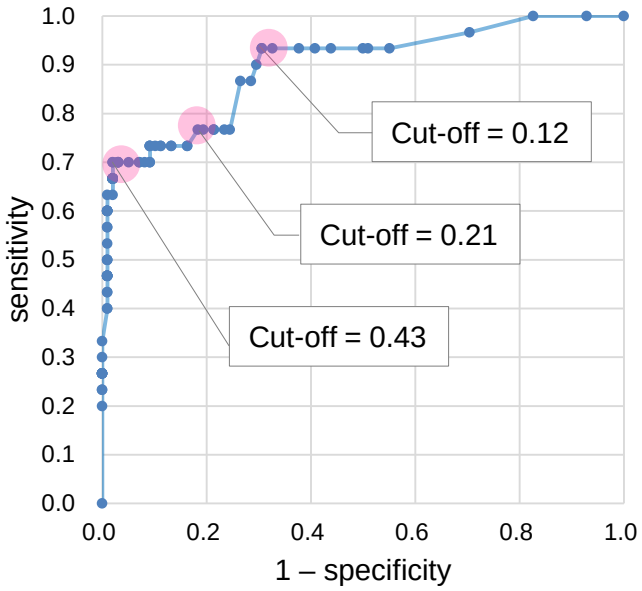
- Objective: Early screening of MID patients
- Approach
  - ✓ Classification method: Binary logistic regression
  - ✓ Selected variables: **TT, ME, IT, age** (stepwise method, $\alpha_{in,\ out} = 0.05$)
  - ✓ Data set: normal controls vs. aMCI + svMCI patients



S4. Diagnostic Model: Performance

❑ Comparison of performance according to cut-off threshold

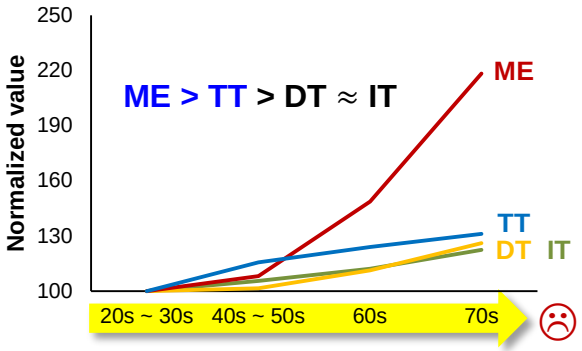
No.	Cut-off	Confusion matrix				Performance (%)		
						Sensitivity	Specificity	Accuracy
1	0.12	*n* = 128		Actual: Normal	Actual: Patient	93.3	69.4	75.0
		Predicted	Normal	**68**	2			
			Patient	30	**28**			
2	0.21	*n* = 128		Actual: Normal	Actual: Patient	76.7	81.6	80.5
		Predicted	Normal	**80**	7			
			Patient	18	**23**			
3	0.43	*n* = 128		Actual: Normal	Actual: Patient	70.0	98.0	91.4
		Predicted	Normal	**96**	9			
			Patient	2	**21**			



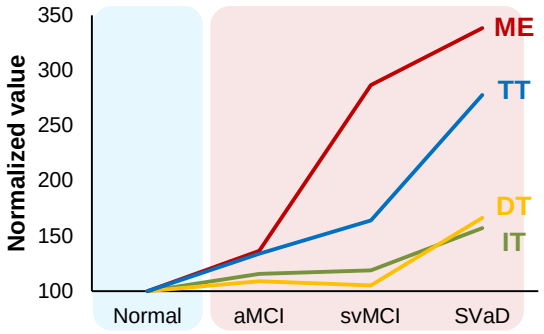
⇒ Maximize **sensitivity** (> 90%) for early screening of **MID**

Discussion

- **Assessment** of FCCs: **comparison** of **MID patients** (aMCI, svMCI, SVaD) with normal controls by **force control phase** (initiation, development, maintenance, termination)
  - ✓ Decrease in motor skills according to **severity**: ☹ **SVaD > svMCI > aMCI**



Age effect on motor skills for normal controls



ME > TT > DT ≈ IT

Motor skills of controls and patients

⇒ **ME, TT**: Discriminant factors ➔ contribute to **distinguish MID patients and controls**

- Diagnostic model development for **early screening of MID**

  (**Sensitivity for MCI = 93%, sensitivity for SVaD = 100%,** specificity = 69%, accuracy = 75%)

⇒ Useful for MID diagnosis in the early stage

Q & A

Thank you for your attention!