Performance & Motor Control
Characteristics of Functional Skills
Fitt’s Law

- Speed-Accuracy Trade Off

- Fitt’s Law provide a mathematical model
  - \( MT = a + b \log_2(2D/W) \)
  - Variables that predict performance is distance to move and target size

- Fitt’s law has an index that measures the difficulty of the task (ID’s
Fitt’s Law

• Applies to any skill where the object of the task is accuracy except bimanual skills.
  – manual aiming task (e.g. placing pegs in board, throwing darts, grasping containers of different sizes, moving cursor across the screen to a word)
  – Kicking a soccer ball to the different location of the goal
    • Greater the area where you want the ball to go, the greater the movement speed of the kick
PREHENSION

• Act of reaching, grasping then manipulating the object.
  – Reaching is the reach or transport phase which
  – Grasping phase
  – Manipulation phase

• Prehension is different from the action of reaching and pointing to an object (aiming skill)
Prehension

• The transport (reach) and grasp seem to be temporally coupled and work cooperatively.
• Vision & the Fitt’s Law works together to control prehension.
  – If the reach is ballistic, the reach occurs without sensory feedback and vision plays only provides:
    • Time to contact information,
    • Displacement information, and
    • Velocity information.
  – If the reach is performed under closed loop control, vision feedback information is used constantly during prehension by the performer.
Role Vision Plays

• Prior to the reach the person uses vision to determine the regulatory conditions of the environment in which the action will occur.
  – Distance & Spatial orientation of the object
  – Location of the object
  – Size of the object
Role Vision Plays

• Vision is very important in the grasp and manipulation stage.
  – Enables one to make *slight corrections* that occur just before the grasp
  – Vision is necessary *when* to grasp
  – *Binocular vision* aids the size of grip and force of grip
  – Person needs to look directly at the object for the grasp (*point of gaze*).
Prehension and Fitt’s Law

Prehension applies to the *speed accuracy trade-off law*, that is, the time of prehension (movement time) is affect by distance of the reach and size of object.
Controversy to Explain Fitt’s Law

- Intermittent feedback hypothesis
- Impulse-timing hypothesis
- Multiple submovements hypothesis
Handwriting

• Difference control mechanism are involved in controlling:
  – What people write (e.g., letters, words)
  – How people write (e.g., writing surface)

• Writing involves both cognitive (retrieve letters, words, grammatical construction, spelling) and motor skills (holding the pen, size of letters).
HANDWRITING

• Based on motor equivalence, that is, one can adapt to specific demands of the writing context

• Motor equivalence provide for similarity in letters and stroke production across many contexts
VISION AND HANDWRITING

1) Vision helps to control the overall spatial arrangement of words on a horizontal line.

2) Vision helps one produce accurate handwriting patterns, that is, stroke pattern and lettering.
Bimanual Control

Bimanual movements involve the limbs moving in same similar pattern (symmetric) or moving each limb differently (asymmetric).

Examples:
- Playing a guitar
- Tying a shoe
- Drummer
- the Serve in tennis
Bimanual Control

Whether we perform symmetric or asymmetric bimanual skills, the two limbs prefer to do the same thing at the same time.

- Rub your stomach with one hand while at the same time tap your head with the other hand. Gradually increase the speed of each action...What happens?
Bimanual Control

Bimanual skills do not apply to Fitt’s law.
- The more difficult task will influence the performance of the less difficult task.
- Temporally moving both limbs eventually overcame the influence of the speed-accuracy tradeoff relationship

Many bimanual skills occur when one limb performs a more difficult task while the other performs an easier task. The more difficult task will always influence the less difficult task.
Bimanual Control

How do we become proficient (uncoupled) in performing bimanual skills?

Answer is we learn to become uncoupled (dissociate) through practice.

Uncoupling is a difficult process for people but given proper instruction, feedback, and practice one can become asymmetric.
Locomotion
Motor Control of Upright Independent Gait (Walking & Running)

Central pattern generators in the spinal cord controls human gait. Evidence is found:

- Decerebrated cats (severing the spinal cord from the brain) can still walk and perform locomotor rhythmic muscular activity (Sherrington, 1906).
- Spinal cord plays a significant role in control of locomotion
Rhythmic Structure of Locomotion

Between the arms and legs due to walking speed.
- **$2:1$ ratio** (two arms swing to each leg stride) exists for slow walking and pelvis and thorax move as one.
- **$1:1$** ratio exists for fast walking but pelvis and thorax are independent in fast walking.

Knowing that distinct rhythmic relationship exist is important in measuring coordination:
- problem in Parkinson’s disease patients
- determine the effectiveness of reconstructive knee surgery.
- patients with have ACL surgery walking phase is greatly altered due to segments of the leg have been changed.
- post stroke patients need for treadmill walking retraining to move both their arms and legs.
Head Stability & Locomotion

Head stability is key factor of the Gait.

The head contains the sensory and motor nervous system components that helps us navigate through an environment and in maintaining one posture.

Maintaining a stable head during locomotion optimizes the use of vision so we can tracking a ball, catch an object, and avoiding objects.

Adults with neurological impairment adopt an abnormal posture and gait as a means to maintain head stability (Holt, et al., 1995)
Visual Cues Aids and Walking

• People who have Parkinson’s disease is slowest in gait.
• Why
  – Stride lengths are very short but rhythm was similar to normal patients
• Rehabilitation strategy
  – Provide visual cues (floor marking) to increase stride length
  – Provide auditory cues (step to tempo) to increase stride length
Gait Transitions

Walk to run or run to walk transitions occur at different speeds.

These changes are spontaneous transitions but they vary between people. Why?

It is not due to physical limitations. The spontaneous transition occurs at a speed where we minimize metabolic energy consumption (VO2).

This assumption has not been totally supported but spontaneous transition remains a puzzle for researchers to solve.
Vision & Locomotion

• Contacting an object

• Avoiding contact with an object
Vision & Contacting Objects

As you walk rapidly down a hallway attempt to make contact with a target placed on the floor.

1) Visional information is used to determine the amount of time it will take to contact the target (time to contact)

2) Time to contact is used to make stride-length adjustments during the last few steps to correct any errors.

3) Time contract is a quality we possess that is not dependent on experience.
First phase of the run-up the stride length correction occurs while the jumper is accelerating followed by a zeroing-in phase where the jumper changes stride pattern to eliminate errors.

**Long Jump Study**

![Graph showing stride length vs. stride number before take-off.](image)

Lee, Leshman, Thomson, 1982
Vision & Avoiding an Object

Make two lines of students in the hallway. Have each line face each other. Have each line begin walking toward each other. The objective is to avoid contacting the students as they walk toward each other.

1. Vision provides the human with body scaled information (size of the object) when we walking through a doorway.

2. Vision provides a predictive information that specifies the type of step-pattern alternation that is needed when we safely avoid an obstacle in our path.
Avoiding Objects As we walk

• If one is to maintain foot speed while avoiding an object three time periods are critical
  – Recognize that an object needs to be avoided*
  – Adjust the foot
  – Turn the foot to avoid the obstacle

*The most critical period is recognizing the object that needs to be avoided

*Training implication is a person must recognize objects sufficiently early to allow appropriate movement adjustments.
Virtual Reality Training

Compared stepping over real or virtual objects on a treadmill as an intervention strategy for poststroke patients.

– One group was the real obstacle training group that wore a gait belt and stepped over foam obstacles in a hallway.
– Second group were placed in a harness, walked on treadmill with head mounted display that showed images of same objects as in real obstacle trained group

Virtual trained group balance, velocity, cadence, strike length, and obstacle clearance showed the greatest improvement.
## Vision & Catching

**Catching**
1) Involves a moving object
2) Grasping the ball is the end movement of catching

**Prehension**
1) Involves a stationary object
2) Prehension involves manipulation of the object
Three Phases of Catching an Object

On initial ball flight, no arm action is seen.
About 25 to 80% of ball flight, elbow flexion and finger extension occurs slowly.
At about 50% to time the ball is caught, the hand withdraw and become spatially positioned.
Shortly before the catch, fingers become positioned.

*Successful catchers had their hands and fingers ready to catch the ball earlier than unsuccessful catchers.
VISION AND CATCHING

• Visual contact is needed during the initial part of flight and period of time just prior to contact with the hand(s)
  – Only the first 300 ms of flight is needed to determine direction & distance.
  – Only the last 200-300 ms before hand contact is critical.

• Viewing the object between these two time periods is not critical to catching

• Performers visually sample the ball flight characteristics (snap shots every 80s of ball flight) to obtain up-to-date information about when they need to catch the ball

• Optical variable tau (time to contact) is involved in solving the time to contact problem in catching
  – An approach object visual size increases (looming) which the visual system uses to determine when collision with the object will occur.
  – An approaching object off the left or right of the body, TAU controls the timing of the reach to catch the object
DOES ONE NEED TO SEE THEIR HANDS TO CATCH AN OBJECT?

• Smyth & Marriott study of seeing or not seeing their hands:
  – Seeing their hands were more accurate
  – All catchers were able to make correct spatial position of their hands to intercept the ball

• Experience in catching is an important factor
  – Experienced catchers do not need to see their hand.
  – Lowly skill catcher do need to see their hands throughout the flight
Vision & Hitting

• Ball viewing or tracking occurs with two systems
  – Image-retina system
    • reads the image of the ball as it washes across the retina
    • Eyes & head do not move
    • Use when viewing the object is short (245 ms or faster)
  – Eye-in-head system
    • Eyes and head move to track the ball
    • Image is maintained on fovea longer
    • Used when viewing the object last 365 ms or longer.

  – Both systems are available to provide information about the object but the transition (shifting) between two systems is long (120ms)

  – Earlier tracking using eye-in-head system is therefore preferred
Vision & Hitting

• Experienced hitters can correctly identify all the pitches (89%) whereas inexperienced hitters cannot (60%).

• Novice hitter fixate at the head of the pitcher whereas elite hitters fixated on the release point of the pitcher.

• Novices tended to saccade before the release of the ball whereas experienced hitters waited until after the release of the ball.
VISION AND HITTING

1. One can see the ball only to the point at which the swing is made (Hubbard & Seng) not to the point of contact.

2. Success in hitting or striking is related to tau-base strategies:
   – Batters synchronize the start of their step to release of the ball.
   – Successful hitter’s duration of the swing to swing was consistent from one swing to another.
   – Initiations of the swing was adjusted according to the speed of the oncoming pitch.
   – Successful hitters use the same visual tracking pattern and had a consistent stance to prepare for the pitch.
   – Less Head movement (less than 1 degree) during the swing across all types of pitches is another factor to successful hitting.
   – All adjustments and decision to swing is triggered by visual information (TAU) that occurs in the first 500 msec of ball flight
   – Last 2/3 of ball flight the striker can only make slight racquet or bat changes
Visual Training

• Experimental evidence is lacking about the effectiveness of general vision training to improve sport performances
  – Sport Vision
  – Eyerobics

• Many common visual functions do improve but research has found that Visual ability is sport specific.
  – Visual training exercises should be sport specific.