FREQUENCY OF VOLUNTARY MOVEMENTS

Voluntary body movements by different animals or birds have characteristic frequency ranges. These frequencies are determined by biomechanics, neuromuscular control, and the physical properties of the body parts.

Humans

1. **Voluntary Limb Movements**:
    - Arm or leg movements during normal walking or running: **1–3 Hz**.
    - Hand oscillations during fine motor tasks: typically around **3–10 Hz**, depending on the task's precision requirements.
2. **Walking and Running Gait**:
    - Normal human walking cadence resonates at **1–2 Hz**.
    - Running or jogging shifts to **2–4 Hz** due to higher energy and force requirements.
3. **General Postural Adjustments**:
    - Subtle balance corrections are within **0.1–0.5 Hz** and are linked to slow, controlled muscular feedback mechanisms.

Animals (Voluntary Movements)
Birds

1. **Flapping of Wings**:
    - Smaller birds (e.g., sparrows): **10–15 Hz**.
    - Medium-sized birds (e.g., pigeons): **4–8 Hz**.
    - Large birds (e.g., albatrosses, vultures): **1–3 Hz** during active flapping.
    - Voluntary gliding adjustments: Very low frequencies, **<1 Hz**, dominated by steady positioning.
2. **Walking/Striding**:
    - Bird gait frequencies depend on size:
        - Chickens: **1–2 Hz**.
        - Ostriches: **0.5–1 Hz** (longer strides and slower cadence).

Mammals

1. **Locomotion (Walking/Running)**:
    - Small mammals (e.g., mice, rabbits): Higher frequencies due to shorter limb lengths, typically **3–8 Hz** during normal movement.
    - Medium-sized mammals (e.g., dogs, cats): **1–4 Hz** depending on stride length and activity (walking, trotting, running).
    - Large mammals (e.g., horses, elephants): Slower gait frequencies:
        - Horses: **1–3 Hz** for walking, up to **5 Hz** for galloping.
        - Elephants: **0.5–1 Hz** during their slow, deliberate steps.
2. **Tail Movements**:
    - Some mammals, such as cats and dogs, exhibit voluntary tail-wagging frequencies in the range of **2–5 Hz**, often correlating with their emotional state or communication.

Fish

1. **Body Oscillations for Locomotion**:
    - Tail movements for swimming: Frequency scales with size and speed.
        - Small fish (e.g., guppies): **2–6 Hz**.

    - Medium fish (e.g., trout): **1–4 Hz**.
    - Large fish (e.g., sharks): **0.5–2 Hz** during deliberate, voluntary swimming.
2. **Fins**:
    - Fins used for voluntary maneuvering (e.g., turning, braking): Frequencies typically range from **1–3 Hz** in most species.

Insects

1. **Wing Movements (Voluntary)**:
    - Although wingbeats often fall into mechanical oscillation categories, insects with controlled flight behaviors, like turning or hovering, may adjust frequencies voluntarily.
        - Smaller insects (e.g., flies): **>50 Hz**, with voluntary adjustments in smaller bandwidths.
        - Larger insects (e.g., dragonflies): Lower wing-beat adjustments of **10–30 Hz**.

Key Insights:

- **Body Size Matters**: Frequency is inversely proportional to size—smaller species tend to operate at higher frequencies for voluntary movement.
- **Energy Requirements**: Higher frequencies correlate with more rapid, fine-tuned movements, while lower frequencies are seen in deliberate, forceful movements.
- **Neural and Muscular Systems**: Neuromuscular latency and feedback loops significantly influence these characteristic frequencies, with faster systems enabling higher movement frequencies.

These findings highlight how species are biomechanically optimized for their voluntary movements, tuned to specific frequency ranges that align with their ecological roles and physical constraints.

In the context of producing voluntary sounds through hand-finger played instruments, the fastest rate of sound production depends on the instrument and the physical limitations of human motor control. Below are estimates for the upper frequency limits of sound production for different hand-finger played instruments:

RATES OF PLAYED NOTES OF MUSIC ON DIFFERENT INSTRUMENTS

Fastest Rates of Sound Production by Instrument

Guitar

- **Fastest Picking/Strumming**:
    - Tremolo picking can achieve up to **12–15 Hz** in expert players (e.g., heavy metal guitarists or flamenco musicians).
    - Strumming (rapid strokes across strings): Typically up to **8–12 Hz** during extremely fast playing.
- **Fingerpicking**:
    - Using alternating fingers, skilled players can produce individual string sounds at a rate of about **6–10 Hz** per finger, resulting in effective rates of **12–20 Hz** when alternating two fingers.

Piano

- **Fastest Repeated Notes**:
    - Skilled pianists can produce repeated notes (e.g., on a single key) at speeds of **8–12 Hz** using rapid finger or wrist techniques.

    - Alternating between adjacent keys (e.g., trills): Speeds up to **10–15 Hz** in advanced pianists.

Violin (and Other Bowed Instruments)

- **Fastest Bowing**:
    - Rapid up-and-down bowing (e.g., spiccato, sautillé) can produce sound frequencies up to **10–12 Hz** during virtuoso-level playing.
    - Fingered notes on the fingerboard: Adjustments between notes can occur at rates of **6–8 Hz**, depending on the musical passage.
- **String Crossings**:
    - Crossing strings with bow or pizzicato can reach effective sound production rates of **8–10 Hz**, limited by bow control and string damping.

Other Instruments

- **Percussive String Instruments (e.g., Harpsichord)**:
    - Due to their mechanical nature, the rate of note repetition depends on both the player's fingers and the instrument's mechanics. Expert players can produce notes at **10–12 Hz** using alternating hands.
- **Drums and Percussive Playing Techniques (e.g., Cajón, Bongos)**:
    - For instruments like a cajón or bongos, where fingers are used percussively, repeated strikes can reach up to **8–10 Hz**.
- **Mandolin**:
    - Mandolin tremolo (rapid picking of a single string): Up to **10–15 Hz** for professional players, similar to guitar tremolo.

Factors Influencing Fast Playing:

1. **Neuromuscular Limitations**:
    - The speed of individual finger movements is often limited to around **8–12 Hz**, as this corresponds to the upper frequency limit of voluntary neuromuscular activation.
2. **Technique and Skill**:
    - Advanced players can push these boundaries using techniques like alternating fingers, wrist movements, or leveraging mechanical advantages (e.g., weighted keys or flexible bowing).
3. **Instrument Design**:
    - Instruments with more responsive mechanics or lighter actions (e.g., digital pianos, certain guitars) allow for faster rates compared to heavier or acoustic counterparts.

These estimates showcase the intersection of human biomechanical capabilities and the design of musical instruments, illustrating how technique, training, and instrument mechanics combine to push the limits of voluntary sound production.

Tempo and Hz Equivalents

1. **Very Slow**:
    - **Largo**: 40–60 BPM → **0.67–1 Hz**
    - **Adagio**: 66–76 BPM → **1.1–1.27 Hz**
2. **Moderate**:
    - **Andante**: 76–108 BPM → **1.27–1.8 Hz**
    - **Moderato**: 108–120 BPM → **1.8–2 Hz**
3. **Fast**:
    - **Allegro**: 120–168 BPM → **2–2.8 Hz**

- **Vivace**: 140–176 BPM → **2.33–2.93 Hz**
- **Presto**: 168–200 BPM → **2.8–3.33 Hz**
- **Prestissimo**: >200 BPM → **>3.33 Hz**

Notes Played Within One Beat

When playing notes faster than the tempo's beat (e.g., 16th notes or 32nd notes), the note frequency increases proportionally. Below are examples for the fastest rates of note production:

1. **16th Notes**:
   - At **120 BPM (2 Hz)**: 16th notes are played at 2×4=8 Hz
   - At **200 BPM (3.33 Hz)**: 16th notes are 3.33×4=13.33 Hz
2. **32nd Notes**:
   - At **120 BPM (2 Hz)**: 32nd notes are 2×8=16 Hz
   - At **200 BPM (3.33 Hz)**: 32nd notes are 3.33×8=26.67 Hz

---

Fast Playing Terms with Hz Examples

Tremolo:

- **Violin tremolo**: Played at speeds up to 10–12 Hz in virtuoso performances.
- **Mandolin tremolo**: Often reaches 12–15 Hz due to rapid alternate picking.

Trills:

- Common rates for trills in fast passages: 8–12 Hz, depending on the instrument and player skill.

Rapid Repeated Notes (e.g., Piano or Guitar):

- Repeating a single note or key can achieve **10–15 Hz** with advanced techniques.

Arpeggios or Scales:

- A professional pianist or guitarist can play arpeggios and scales at speeds producing note rates of **10–20 Hz**.

By adding Hz to these musical speeds, we can connect the physical phenomenon of frequency with the musical interpretation of tempo and note production.