

# A Hard Day's Math: Connections Between Mathematics and Music

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Music is full of mathematics—from sums of trigonometric sound waves that comprise audio recordings to transitions between melody notes, between chords, and between onsets in a rhythmic pattern. A variety of mathematical tools (including calculus, linear algebra, number theory and combinatorics) are available for both musical analysis and generation. We will discuss: how patterns and transformations play a significant role in musical aesthetics; why we are drawn to the repetitive nature of the blues; why the bridge of I Want to Hold Your Hand is so mathematically perfect; what statistics and machine learning can say about music authentication; and how Fourier transforms can unravel a few musical mysteries surrounding A Hard Day's Night.



Figure 1: *The Lads*

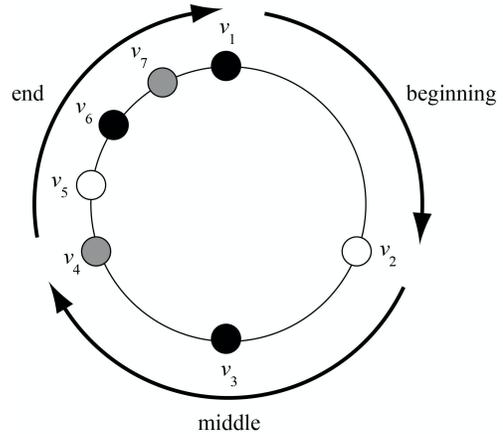


Figure 2: *The Graph*

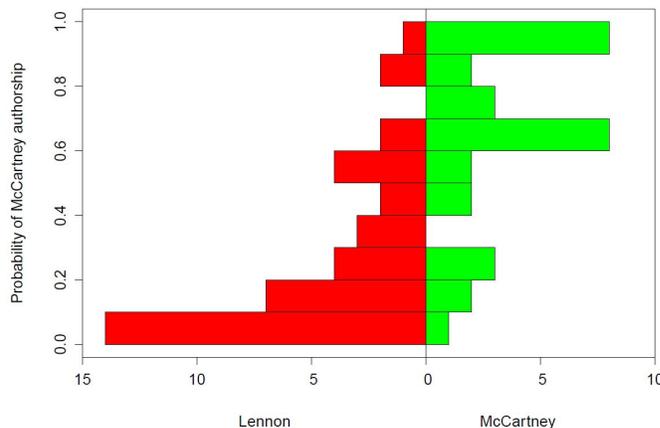


Figure 3: *The Songs*

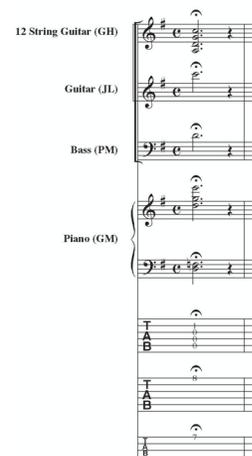


Figure 4: *The Chord*