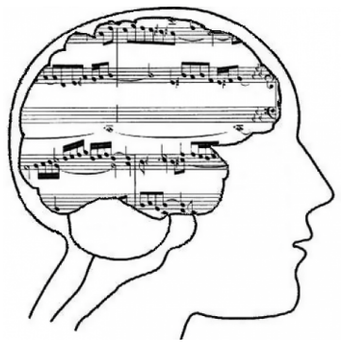

From Neural Networks to Music Technology for Healthcare: An Overview of Recent Research from IHPC Music Cognition

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IHPC Music Cognition

<u>Three main research areas</u>:

1. Learning, memory, and education

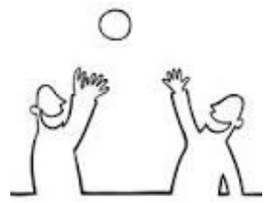
2. AI & Music

3. Music applications for healthcare and well-being

www.a-star.edu.sg/ihpc/Research/Social-Cognitive-Computing-SCC/Music-Cognition

What do these things have in common?

Prediction and expectation



- *Our brains are not passive!*
- **Expectation mechanisms** are of fundamental importance
  - Motor planning, language processing, social interaction, emotional responses, memory… and music!
  - Allow **efficient information processing** in a world that bombards us with sensory information
- **Statistical Learning (SL)** = Ability to *extract statistical regularities* from the world *in order to learn* about the environment

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SL and Music

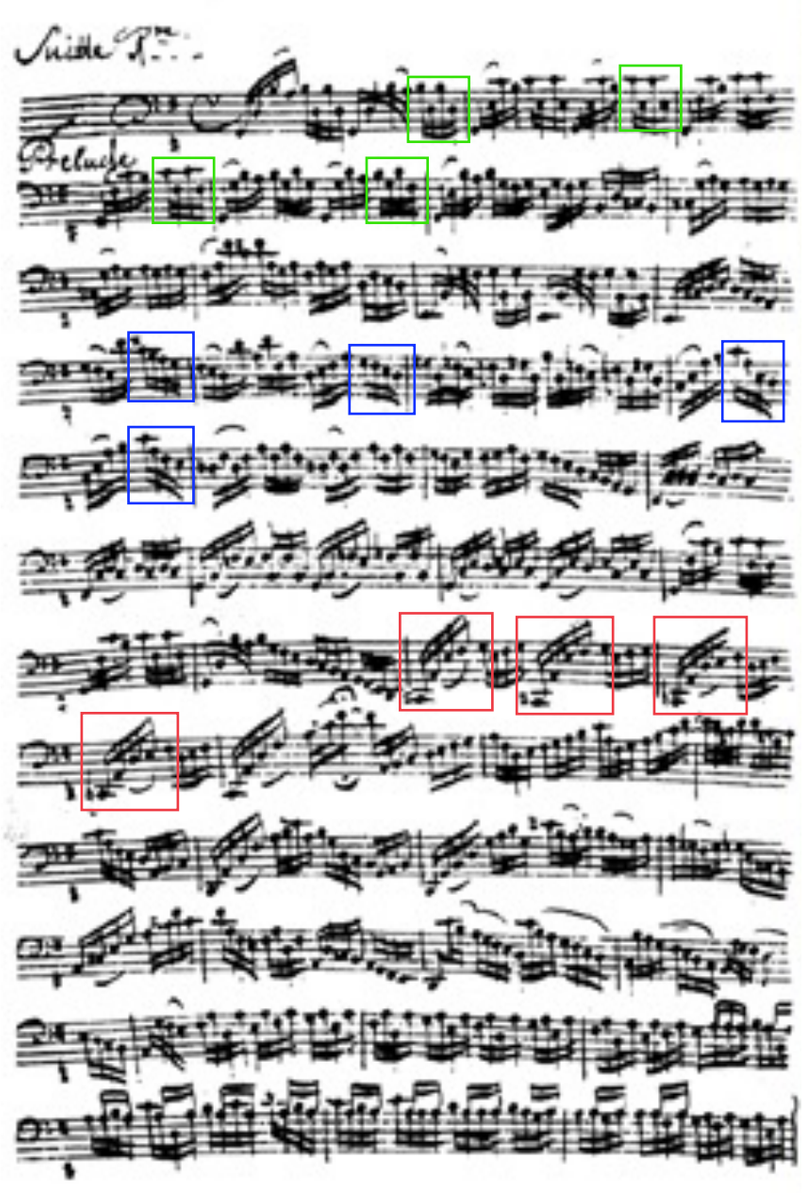
Statistical structure shapes our perception of music!

During music listening, we form

implicit mental models of music

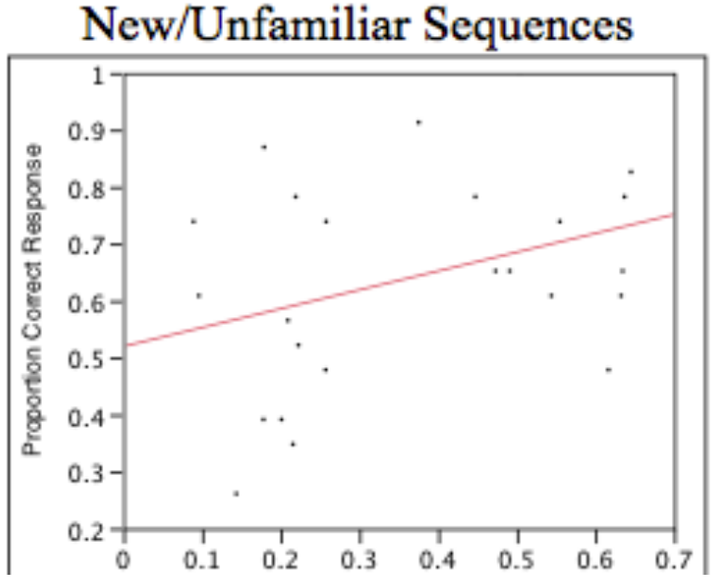
that guide our expectations,

and shape how our brain perceives music.

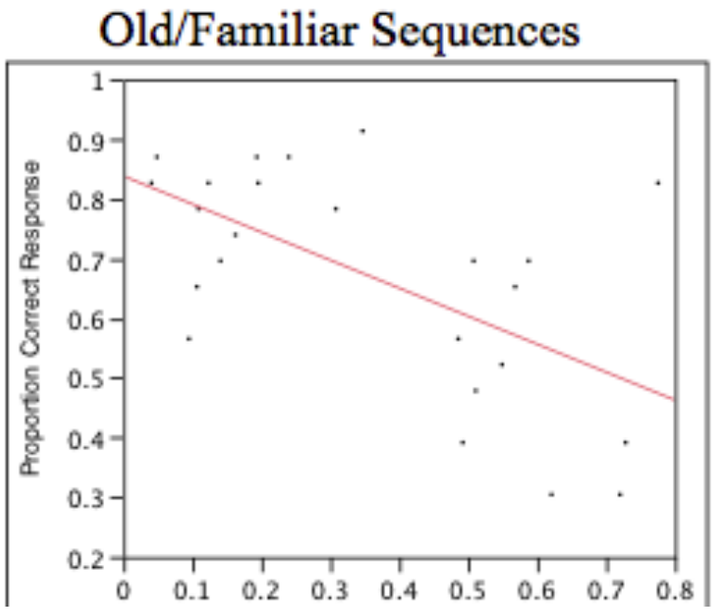


Other kinds of SL in music

- **The stats**: Not only about sequential probabilities!
- Quantified Information-Theoretic structure
- <u>Expectation of an event</u> is influenced by the event's predictability, but *also* the predictability of the entire sequence in which it is embedded
- Predictable sequences yield increasingly better <u>memory</u> performance with increasing exposure



More predictable —> less predictable

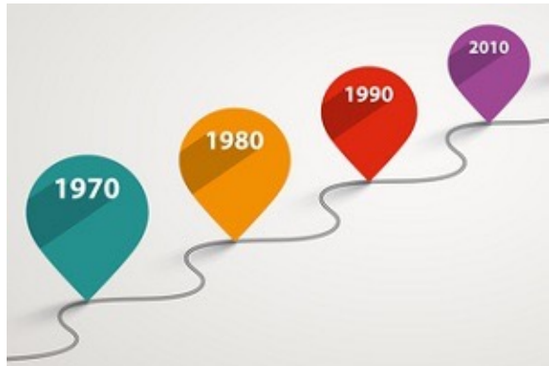


More predictable —> less predictable

Agres, K., Abdallah, S., & Pearce, M. (2017). Information Theoretic Properties of Tone Sequences Dynamically Influence Expectation and Memory. *Cognitive Science*. DOI:10.1111/cogs.12477.

SL on large time scales

- Many studies focus on what a listener can learn over the course of a study (brief exposure)…

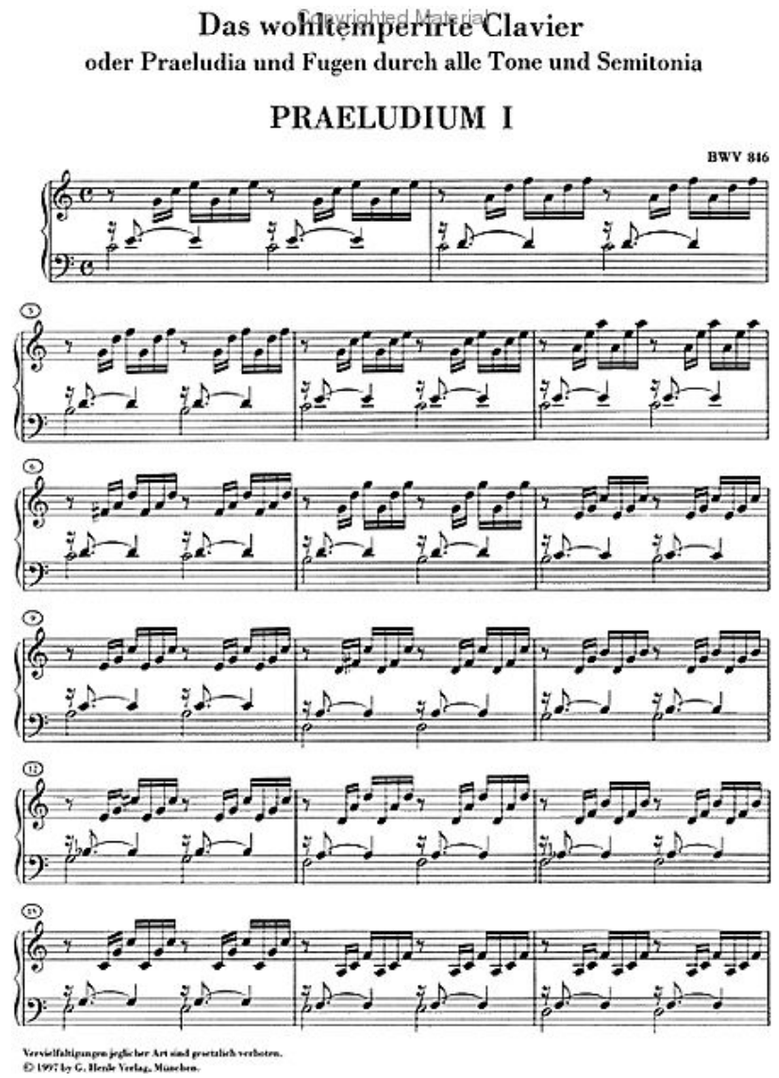


- But statistical learning operates over very long time scales, with big consequences
  - Ex.: Through simple exposure in our daily lives, we implicitly distill statistical properties of entire genres

How can we test this kind of high-level knowledge? Can AI/computational systems learn these statistical properties too, without being explicitly programmed to do so?

Computational & AI approaches

- RBMs, deep predictive NNs
- Examine schematic (general) musical knowledge in listeners
- Computational simulation of how humans learn tonal relationships in music
- No hard-coded musical rules; models use unsupervised learning to extract tonal relationships from the corpus



Cancino, C., Grachten, M., & **Agres, K.** (2017). From Bach to the Beatles: The simulation of human tonal expectation using ecologically-trained predictive models.Proceedings of the 18th International Society for Music Information Retrieval Conference (ISMIR). Suzhou, China.

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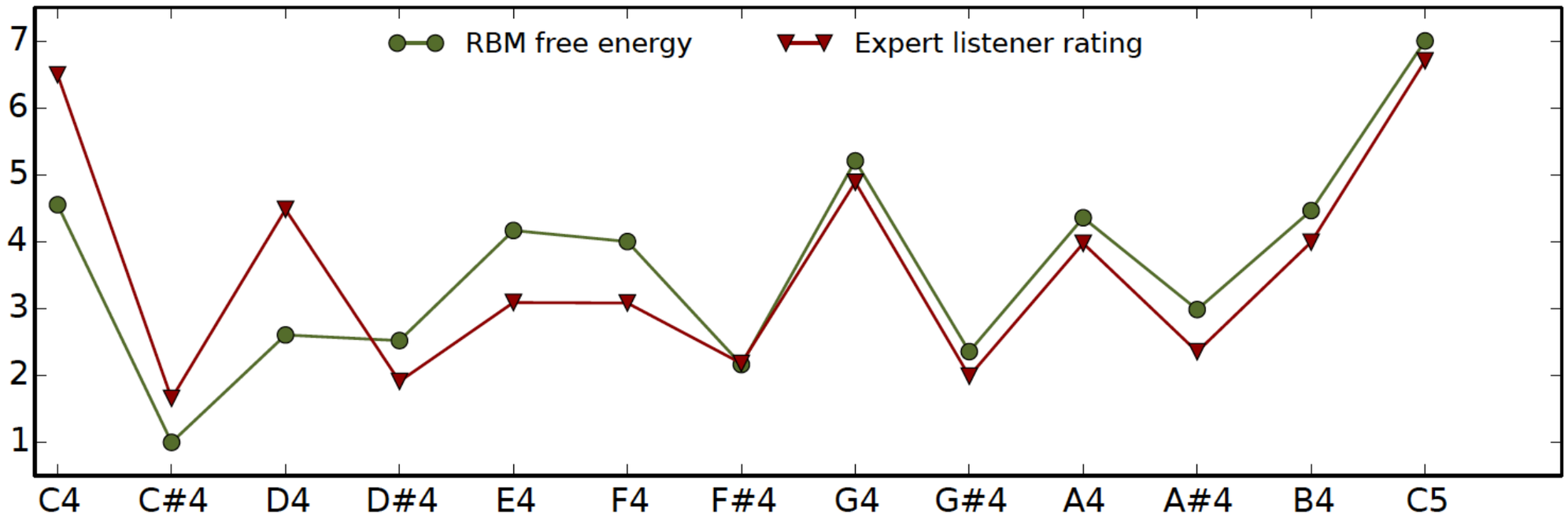
Modeling music perception

- Compare listeners' ratings with our computational RBM model's output ("free energy") on a Probe Tone Task (Krumhansl & Kessler, 1982)

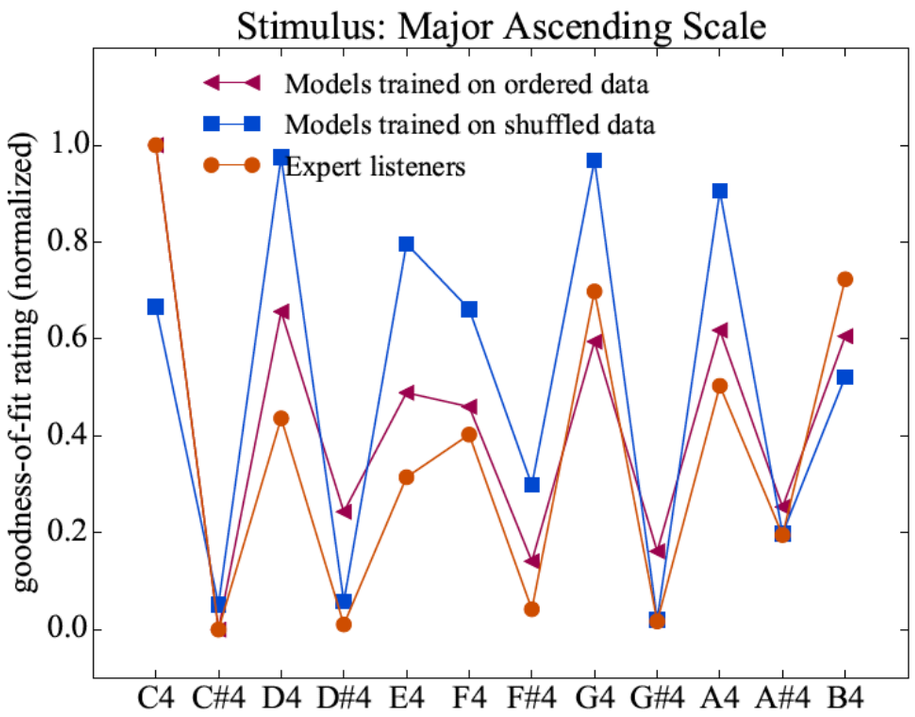


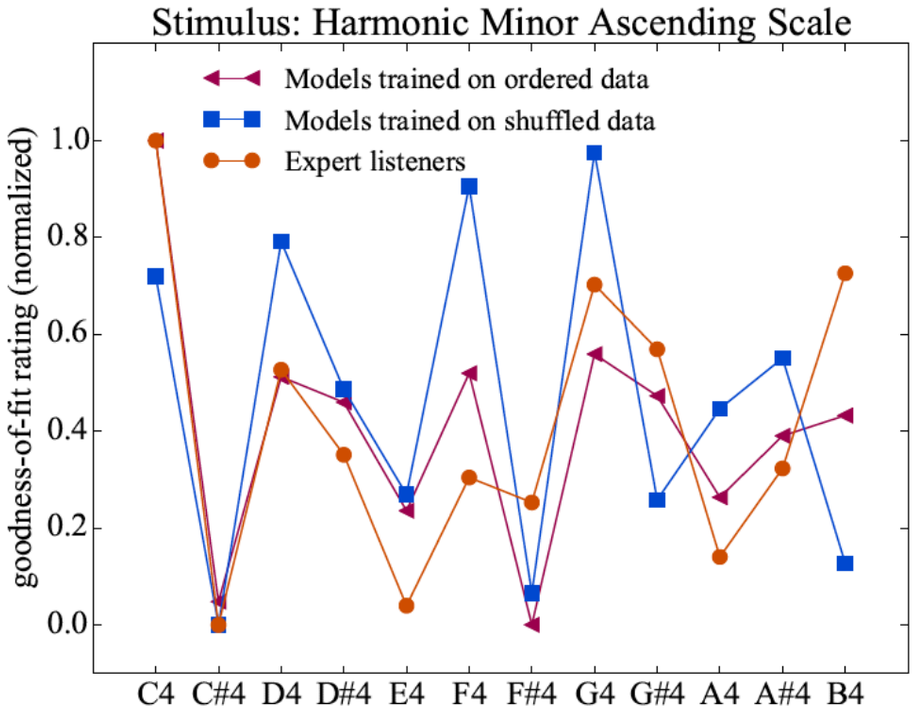
Our model is able to simulate how expert musicians perform on this music perception task

Simulating musical expectation

- Compared musician's probe tone ratings with average expectations of **predictive models** (LSTM, RNN and GRU models)

- Included "**shuffled data**" condition to test what contributes to tone profiles: **global pitch distribution** or **voice leading** and pitch proximity?





Cancino, Grachten, & Agres (2017)

Simulating musical expectation

But what's the point??

To understand and simulate how human minds perceive music!

Our work has shown that:

- NNs can simulate human statistical learning, segmentation, pitch perception, and tonal knowledge
- Different models, input representations, and training corpora can be used to simulate listeners with different expertise/experience

Modeling emotion

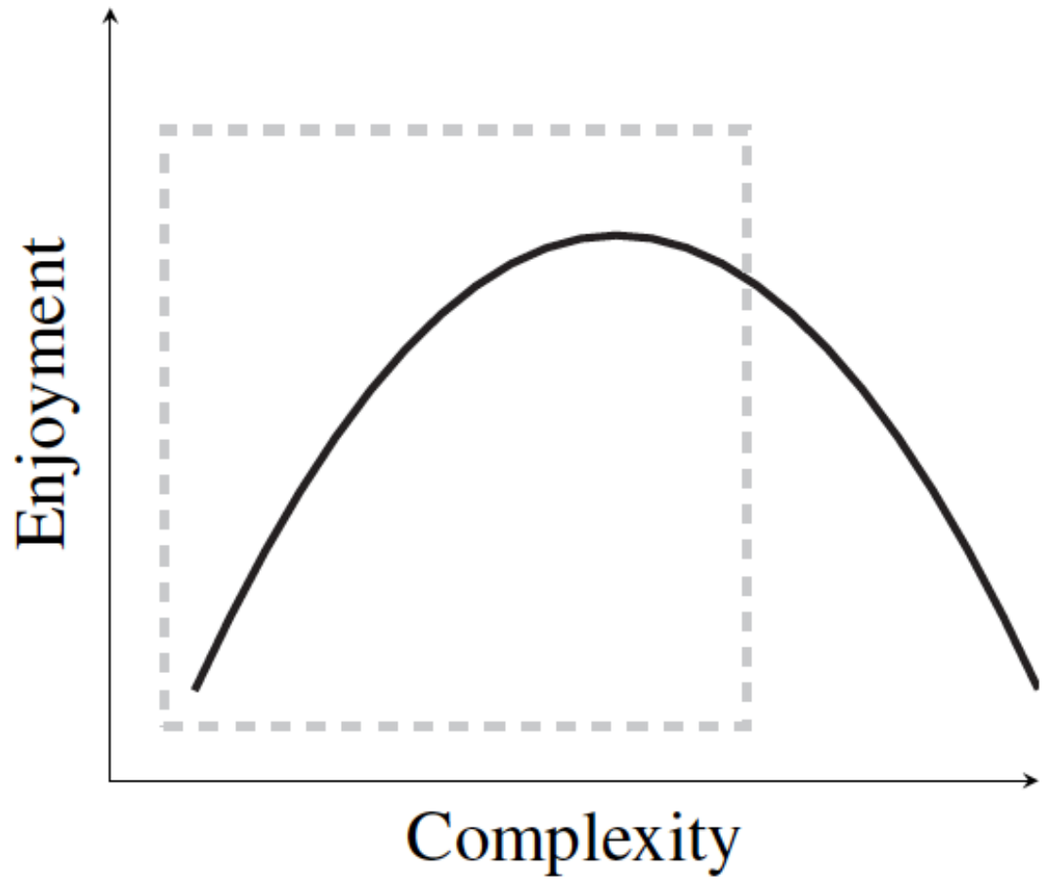
What else does statistical structure of music influence?

As we have seen, the predictability of auditory sequences influences learning and memory, **but how does this structure influence affective response?**

Impact of musical structure on affective response

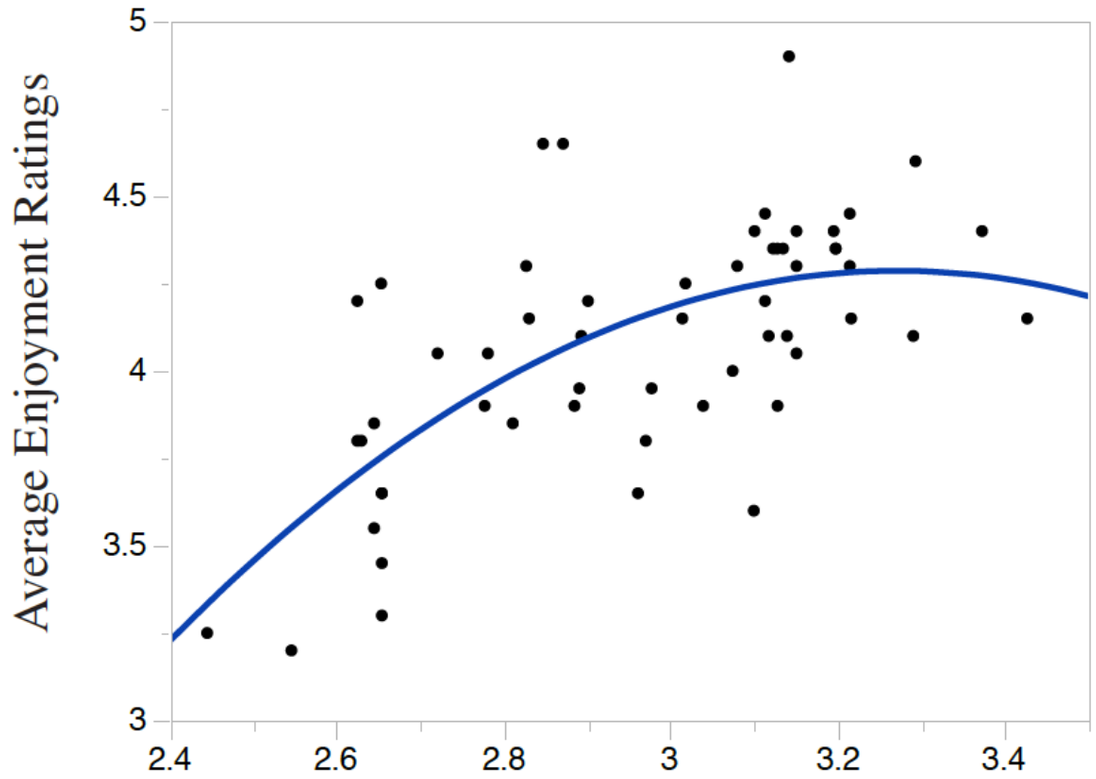
Quantified musical complexity using Information Content

Hypothesis: Inverted-U relationship



Impact of musical structure on affective response

- Two computational models provided evidence for the inverted-U relationship
- Listeners prefer *moderately* complex harmonic structure



Less complex —> more complex

Agres, K., **Herremans, D.**, Bigo, L., & Conklin, D. (2017). The Effect of Harmonic Structure on Enjoyment in Uplifting Trance Music. *Frontiers in Psychology: Cognitive Science.* 7:1999. DOI:10.3389/fpsyg.2016.01999.

Translational research directions

How do we translate SL and Music Cognition findings into healthcare contexts to improve people's lives?

Musical SL for cognitive assessment

- **Cognitive screening using music**: SL performance as cognitive assessment
  - Study in conjunction with IMH, Duke-NUS
  - Upcoming EEG SL study with NUS Psychology, IMH, Duke-NUS, NTU, NUS Psychological Medicine
- Goals: Investigate SL in the elderly, analyse the relationship between individual SL ability and performance on a battery of cognitive assessments.

Is SL ability a potential marker of cognitive function?
Use SL task for early detection of cognitive decline in the elderly?

In collaboration with **Steffen Herff**

Music and motion detection games

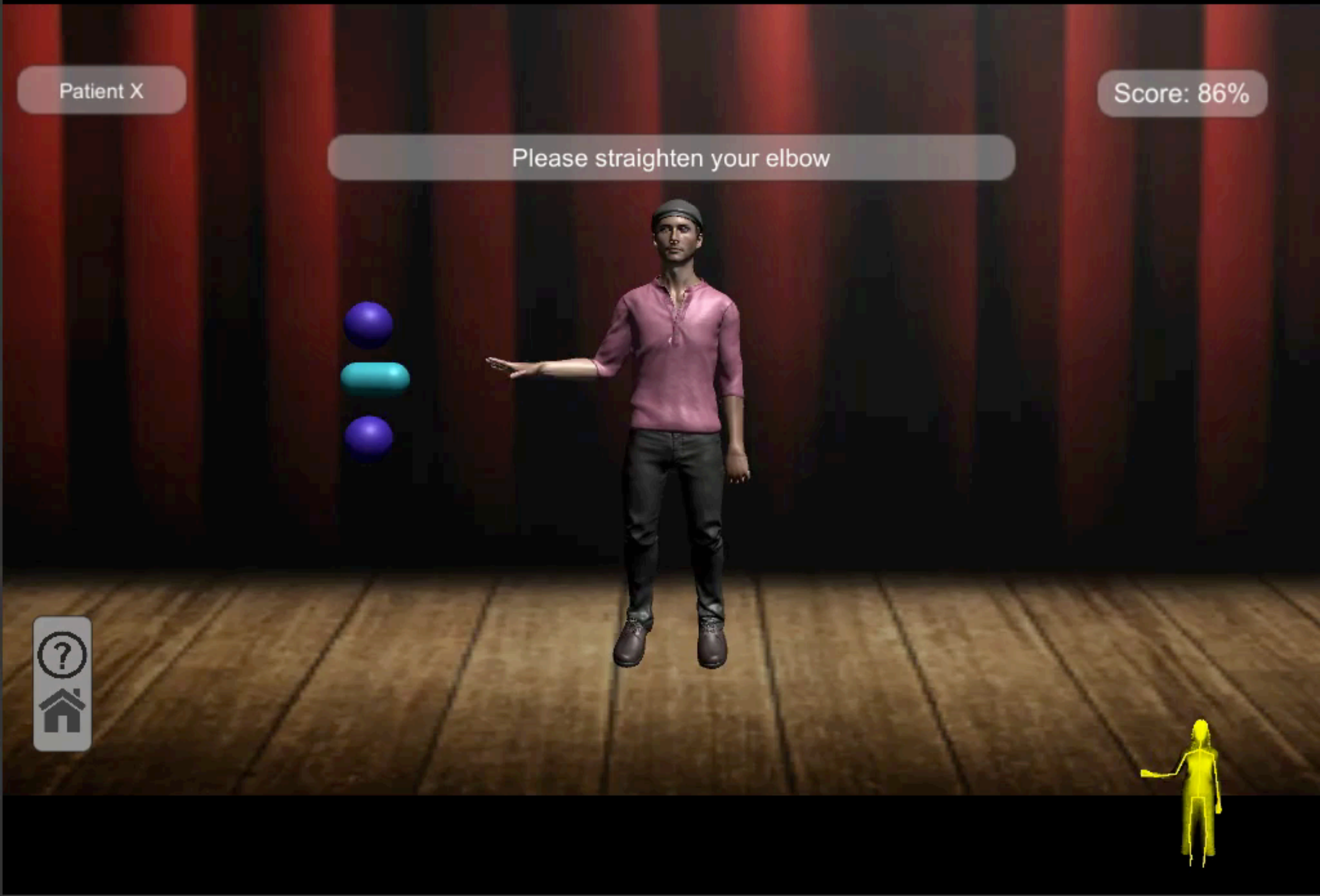
- ☑ Two types of music games:
  1. To support **stroke rehabilitation**
  2. As **preventive medicine** (supporting cognitive function and strengthening) for the elderly

- ☑ **Tele-rehab**: Track patients' progress across sessions
- ☑ **Customizable**: difficulty of exercises tailored to individual abilities
- ☑ **Suitable for elderly users**: simple user interface, straightforward task
- ☑ **Dynamic feedback** about the patient's movements **in real time**
- ☑ **Incorporates music** to engage users, improve motivation and to tap into the therapeutic aspects of music
- ☑ **Automatic evaluation** of range of motion, etc

Agres & Herremans (2017)

- In collaboration with **Praveena Satkunarajah**

Demo!



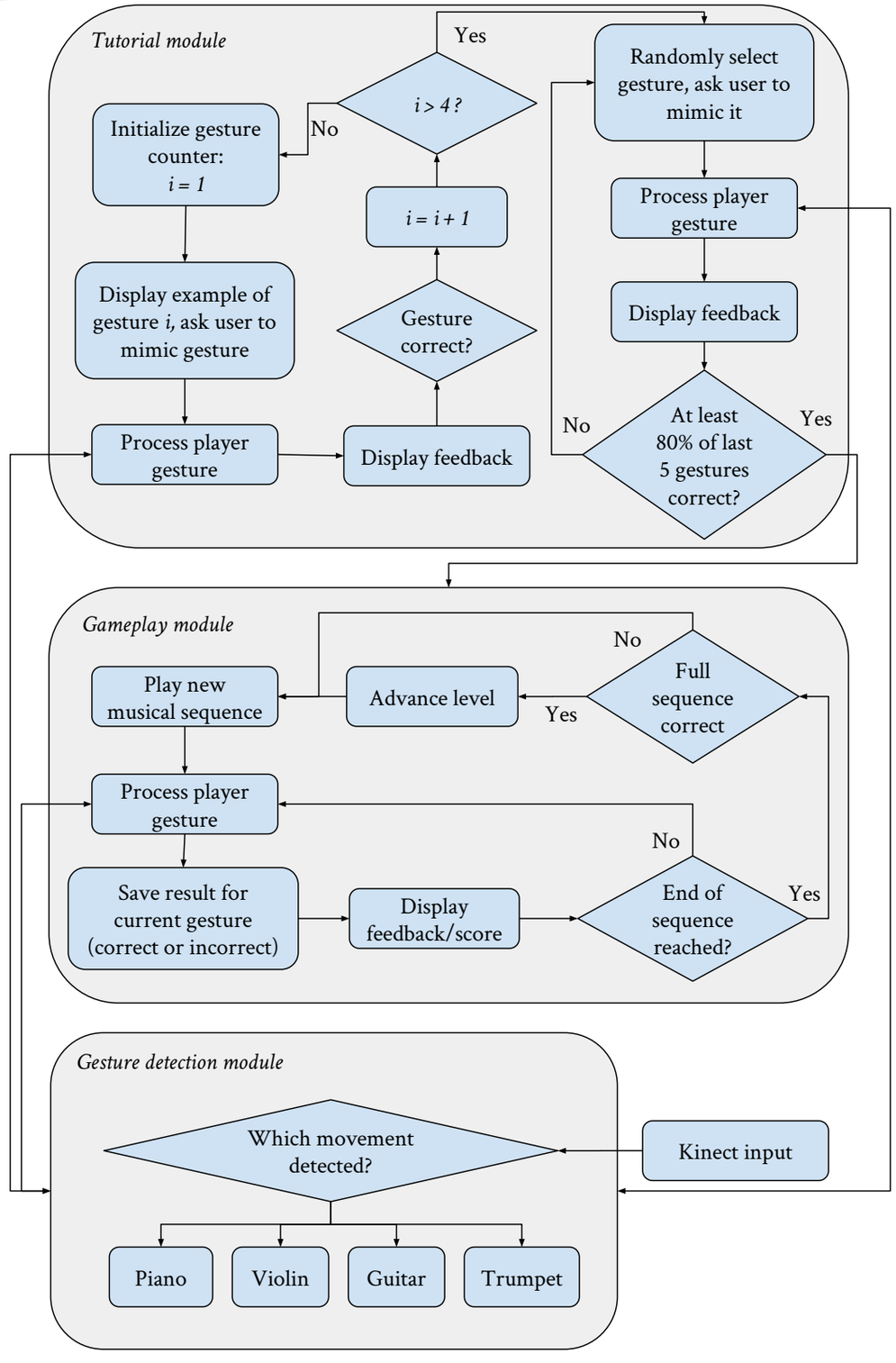
Prototype game for preventive medicine

System Overview:

- Serious game to support **cognitive function** and **motor control** in the elderly
  - Hear melody - 4 solo excerpts
  - Task: Remember sequence of instruments from novel melody
  - Users *perform gestures* for violin, trumpet, piano, and guitar to indicate responses

Agres, Lui, & Herremans (submitted)

In collaboration with SUTD UROP students



Prototype screenshot

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Thanks for listening!

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