KING'S College LONDON

CMPCP

AHRC Research Centre for Musical Performance as Creative Practice

How musicians' and non-musicians' approaches to gestural representations of sound differ: findings from a motion-capture experiment

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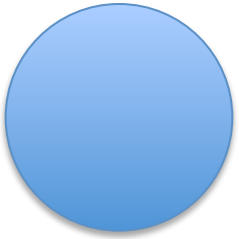
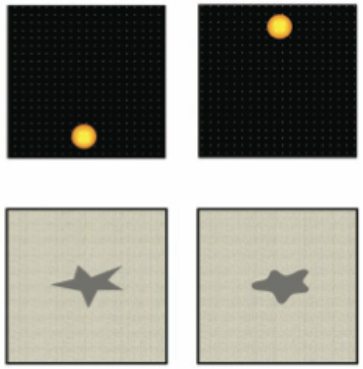


Cross-modal correspondences

- louder sounds associated with
  - larger objects
  - greater brightness
  - higher contrast
- higher pitch associated with
  - greater brightness
  - higher elevation in space
  - smaller objects
  - spikier shapes

Where do they come from?

- Innate

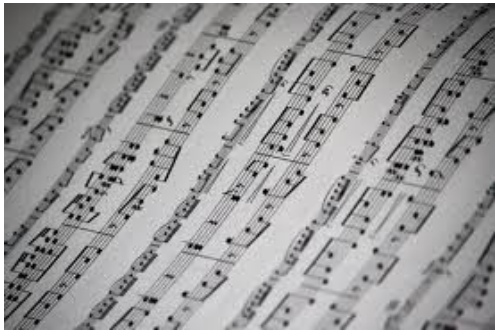


taken from Walker et al., 2010

taken from Ludwig et al., 2011

- Learned
  - (passive) statistical learning

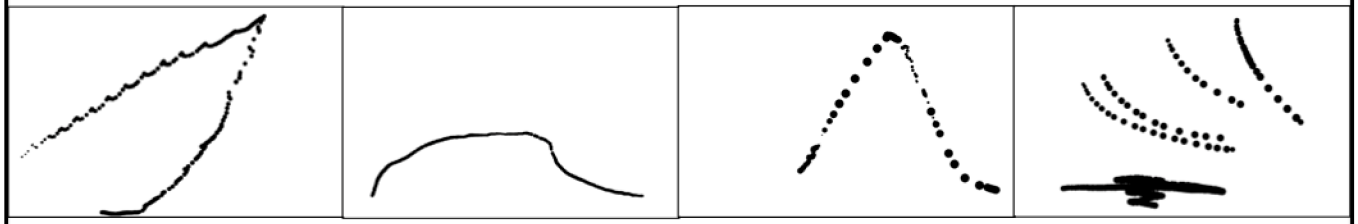
  - metaphor
  - specific training



Küssner (2013)

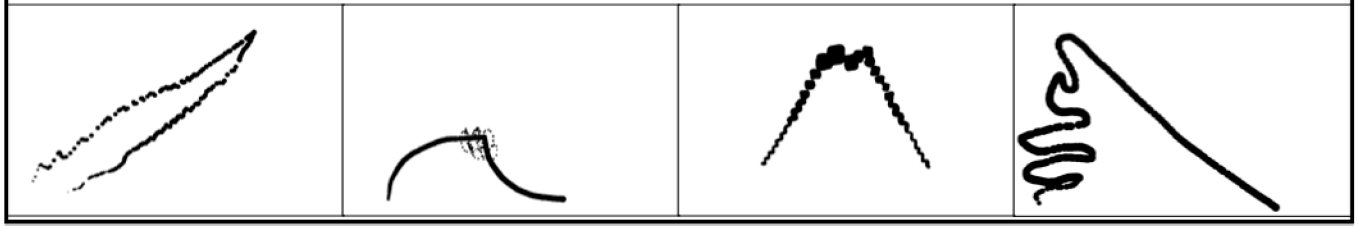
Performance part: sound stimulus 14 (pitch: up-down, amplitude: constant, tempo: decelerando-decelerando)

ppt_55 (non-mus)	ppt_02 (composer)	ppt_54 (visual artist)	ppt_24 (dancer)
glo_rho (pitch): 0.5216*	glo_rho (pitch): 0.9324*	glo_rho (pitch): 0.8773*	glo_rho (pitch): 0.4096*
glo_rho (loud): 0.3753*	glo_rho (loud): 0.5175*	glo_rho (loud): 0.4169*	glo_rho (loud): [0.1574*]
rho (pitch): 0.9601*	rho (pitch): 0.9762*	rho (pitch): 0.9875*	rho (pitch): 0.2433*
rho (loud): 0.3384*	rho (loud): -0.4141*	rho (loud): 0.0573	rho (loud): [0.1104]

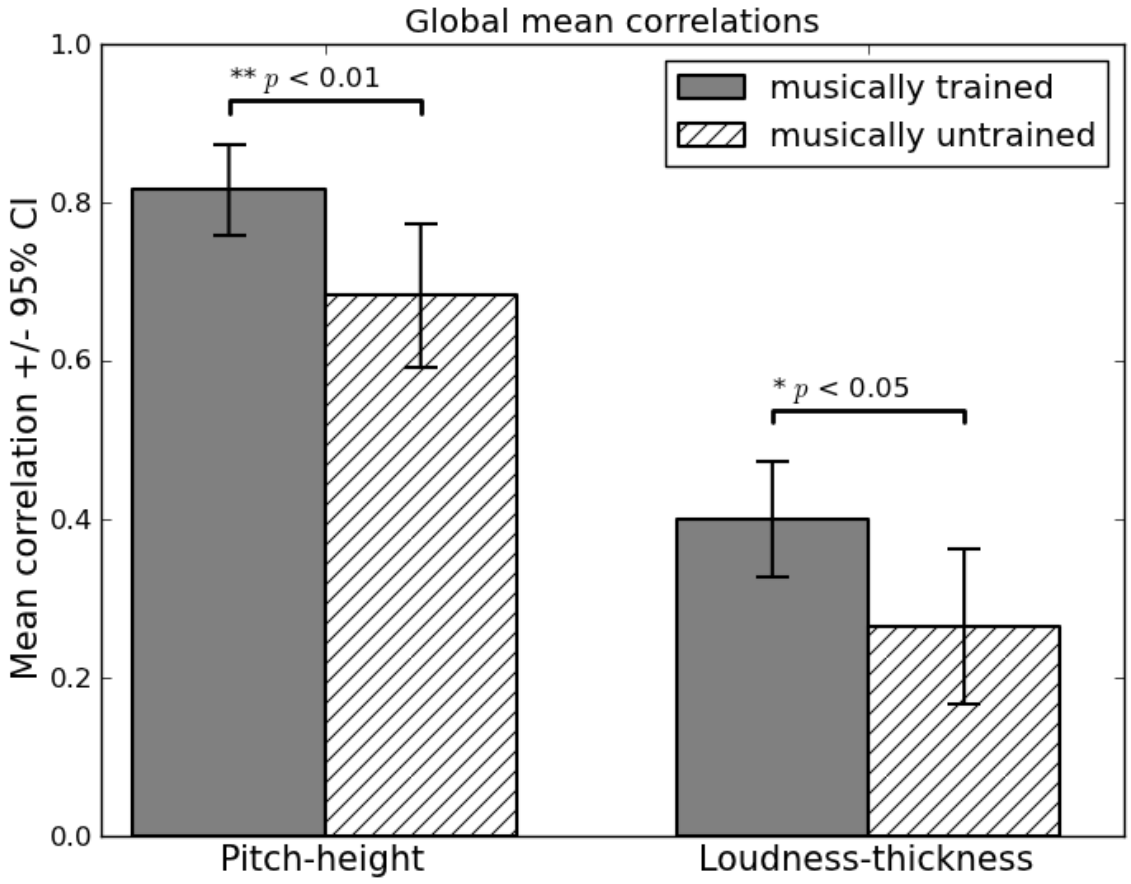


Contemplation part: sound stimulus 14 (pitch: up-down, amplitude: constant, tempo: decelerando-decelerando)

ppt_55 (non-mus)	ppt_02 (composer)	ppt_54 (visual artist)	ppt_24 (dancer)



Küssner & Leech-Wilkinson (in press)



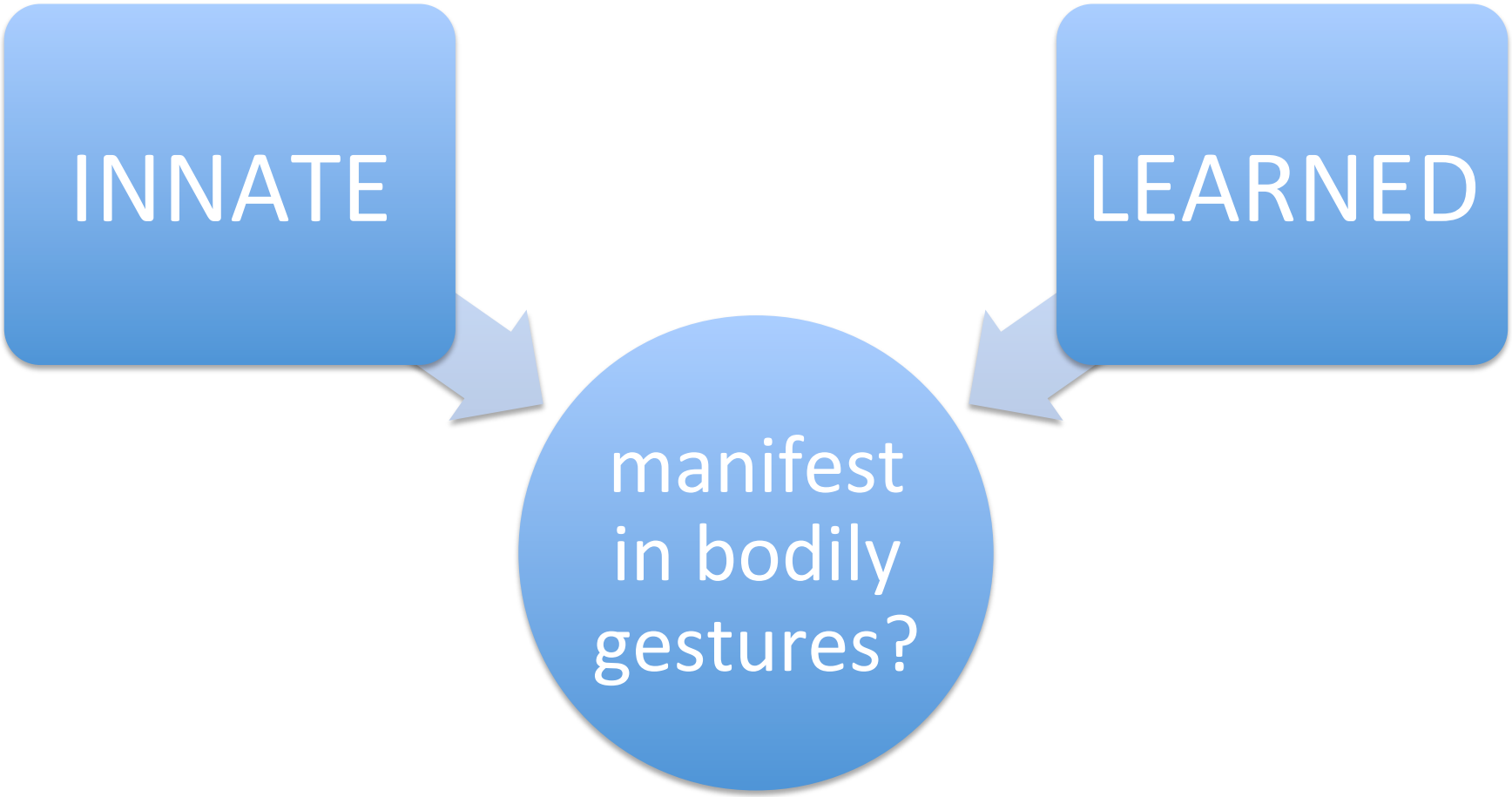
Interactions and Asymmetries

- Eitan & Granot (2006)
  - pitch is mapped onto all three spatial axes
  - pitch fall strongly associated with verticality, but pitch rise only weakly so
  - increasing loudness associated with approaching and accelerating motion (but not an ascent), while decreasing loudness associated with moving away and with descending motion.

Eitan & Granot, 2006

- "This article presents an empirical investigation of the ways listeners associate changes in musical parameters with physical space and **bodily motion**."

Cross-modal correspondences



Research Questions

How does musical training influence gestural cross-modal mappings of musical characteristics?

To what extent does a real-time visualization of the gestures influence these mappings?

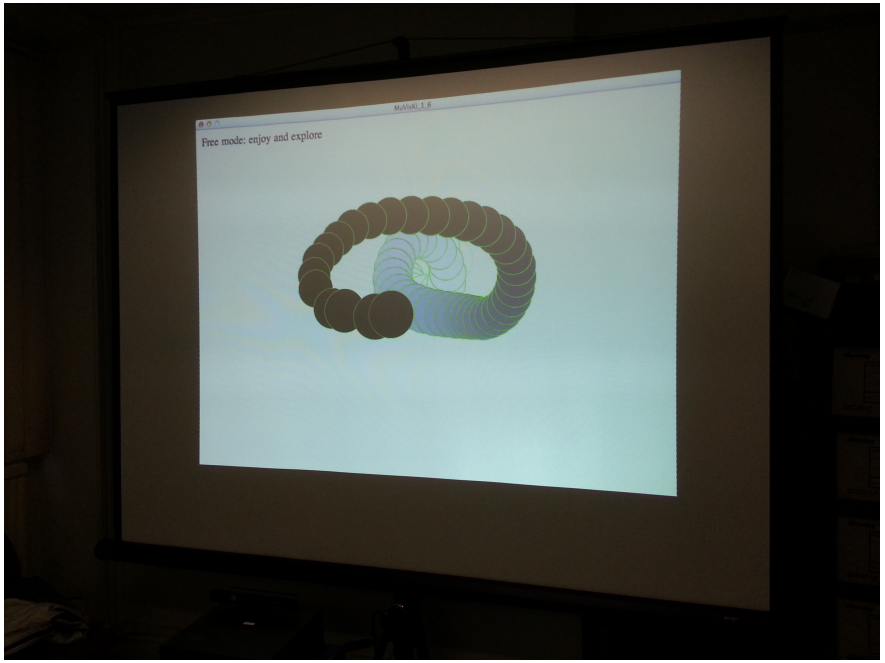
Participants

- 64 (32 female, mean age: 29.63 years [SD=12.49])
- 32 musicians (16 female, mean age: 30.09 [SD=13.66])
  - 8 keyboard / wind / string / composer
  - ≥ Grade 8 ABRSM, ≥ 4 hours per week
- 32 non-musicians (16 female, mean age: 29.16 [SD=11.39])
  - ≤ Grade 1 ABRSM, stopped playing more than 6 years ago and never played longer than 2 years

Stimuli

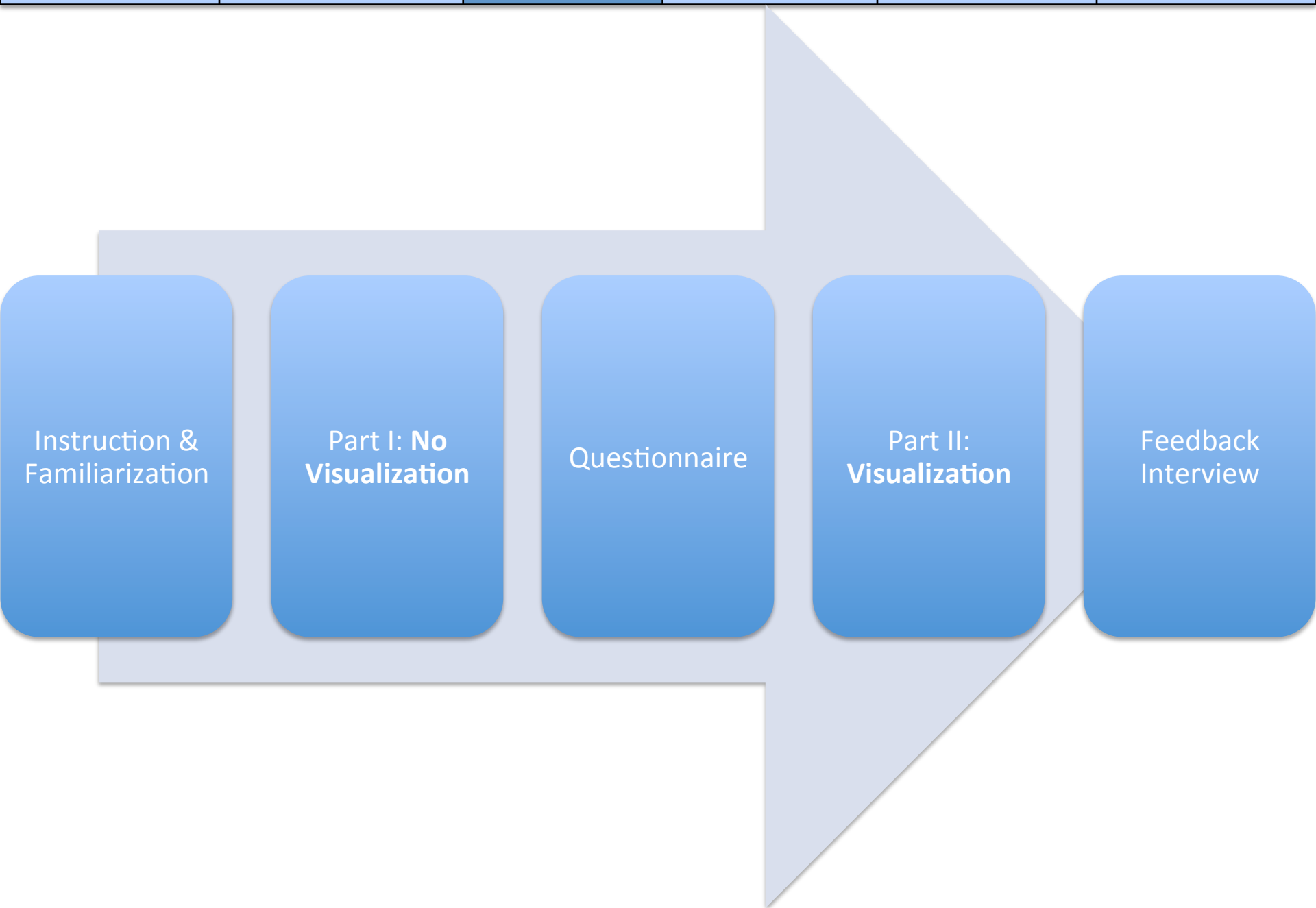
Table 1. Overview of experimental sound stimuli

No.	Length	Frequency (Note name)	Amplitude	Rate of frequency change
1	8 sec	constant (D4)	constant	N/A
2	8 sec	constant (D4)	decreasing - increasing	N/A
3	8 sec	constant (D4)	increasing - decreasing	N/A
4	8 sec	up - down (B2–D4–B2)	constant	equal
5	8 sec	up - down (B2–D4–B2)	constant	decelerando - decelerando
6	8 sec	up - down (B2–D4–B2)	constant	accelerando - accelerando
7	8 sec	up - down (B2–D4–B2)	decreasing - increasing	equal
8	8 sec	up - down (B2–D4–B2)	decreasing - increasing	decelerando - decelerando
9	8 sec	up - down (B2–D4–B2)	decreasing - increasing	accelerando - accelerando
10	8 sec	up - down (B2–D4–B2)	increasing - decreasing	equal
11	8 sec	up - down (B2–D4–B2)	increasing - decreasing	decelerando - decelerando
12	8 sec	up - down (B2–D4–B2)	increasing - decreasing	accelerando - accelerando
13	8 sec	down - up (D4–B2–D4)	constant	equal
14	8 sec	down - up (D4–B2–D4)	constant	decelerando - decelerando
15	8 sec	down - up (D4–B2–D4)	constant	accelerando - accelerando
16	8 sec	down - up (D4–B2–D4)	decreasing - increasing	equal
17	8 sec	down - up (D4–B2–D4)	decreasing - increasing	decelerando - decelerando
18	8 sec	down - up (D4–B2–D4)	decreasing - increasing	accelerando - accelerando
19	8 sec	down - up (D4–B2–D4)	increasing - decreasing	equal
20	8 sec	down - up (D4–B2–D4)	increasing - decreasing	decelerando - decelerando
21	8 sec	down - up (D4–B2–D4)	increasing - decreasing	accelerando - accelerando


Free mode: enjoy and explore

Gesturing conditions

- Instruction: represent sound gesturally while it is played
- "No Visualization": participants saw a white screen in front of them
- "Visualization": participants saw real-time visualization on screen in front of them
- Participants were presented with the same set of 18 stimuli in both conditions

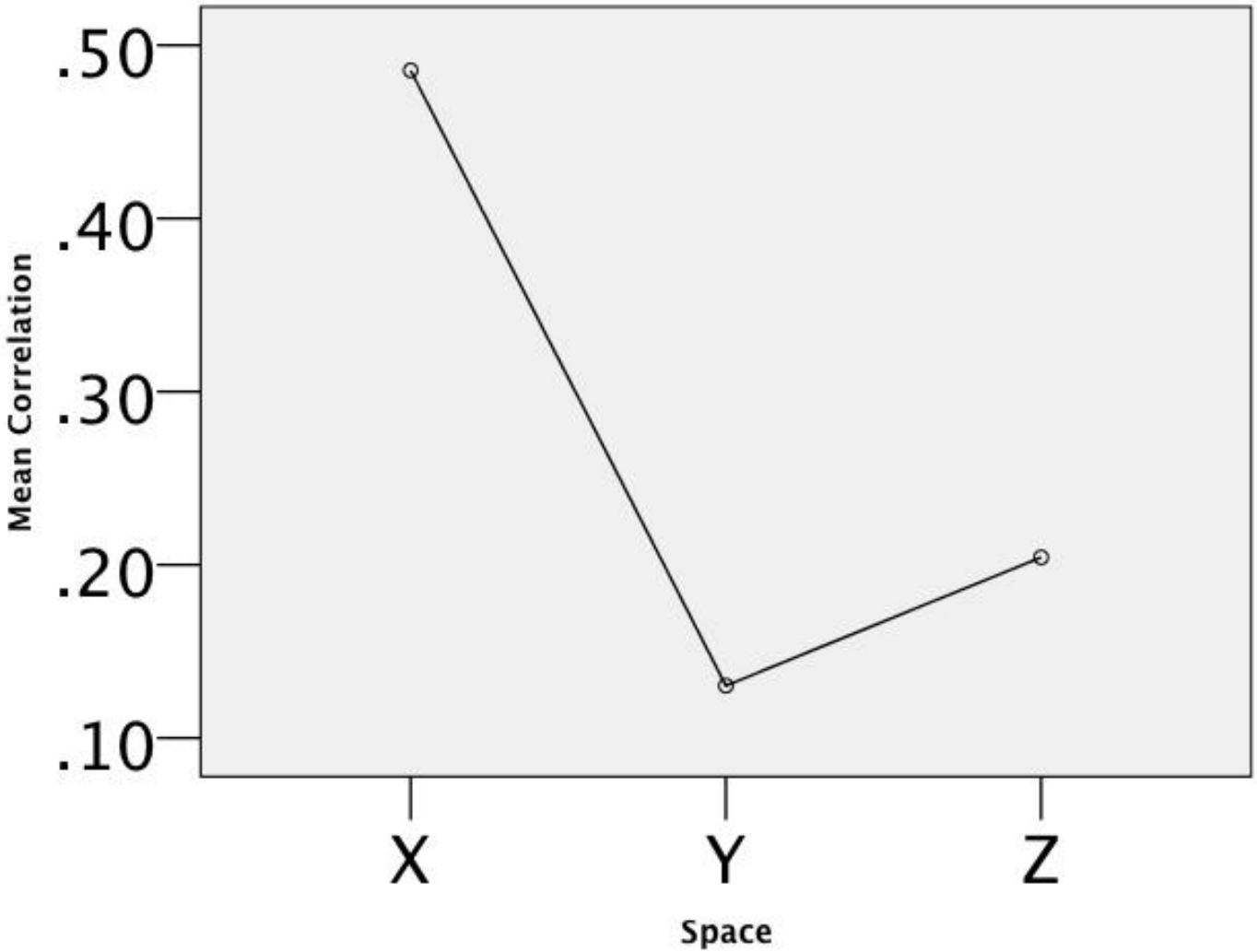

Instruction & Familiarization
Part I: **No Visualization**
Questionnaire
Part II: **Visualization**
Feedback Interview

Analysis

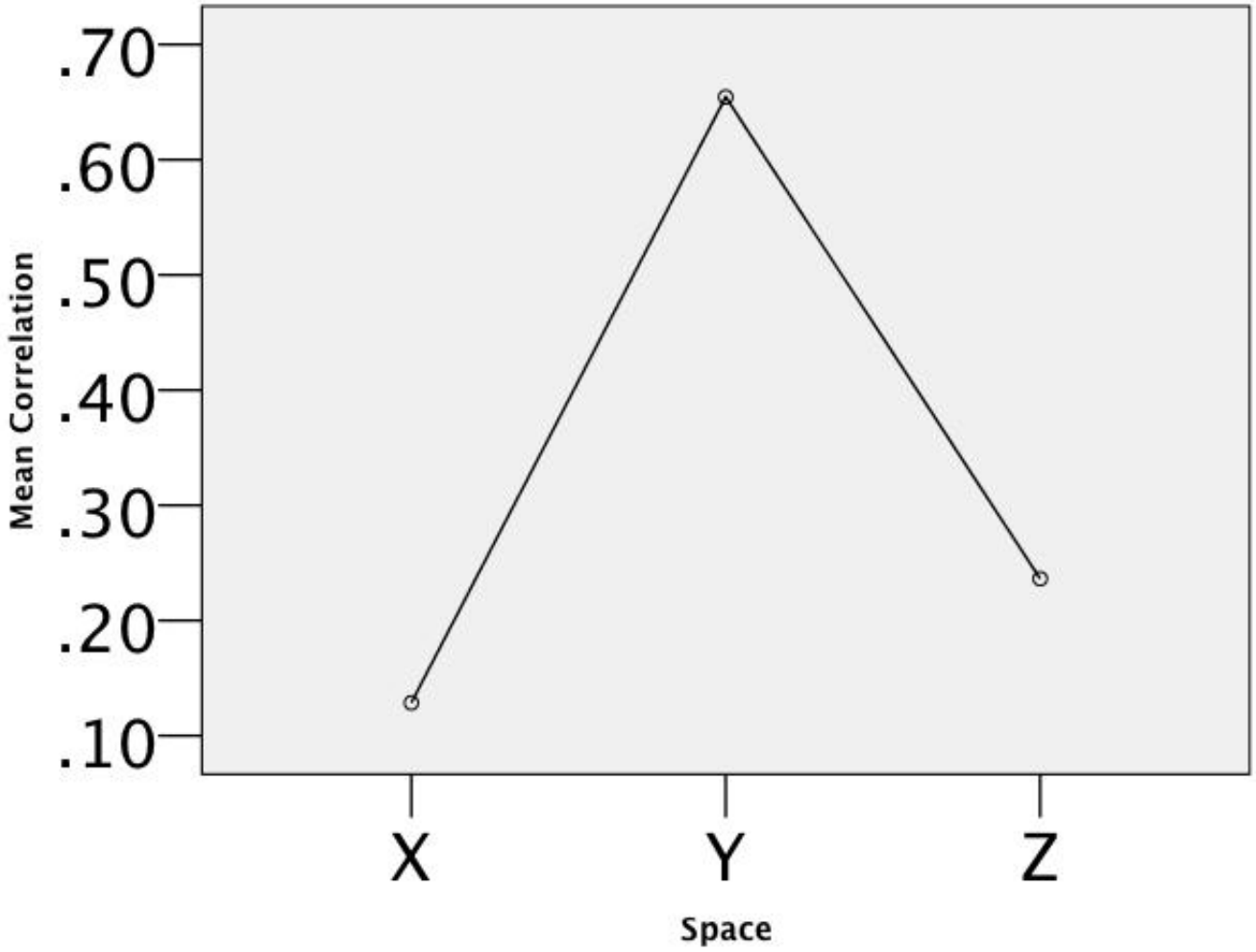
- Global correlations between sound characteristics (pitch, loudness, [time]) and movement (X, Y and Z)
  - resulting in 9 correlation coefficients per participant
- mixed ANOVAs for each sound characteristic with within-subjects factors ‘space’ and ‘vision’ and between-subjects factor ‘musician’
  - dependent variable: correlation

Which spatial axes did participants use to represent (elapsed) time, pitch and loudness?

TIME: main effect of 'space'



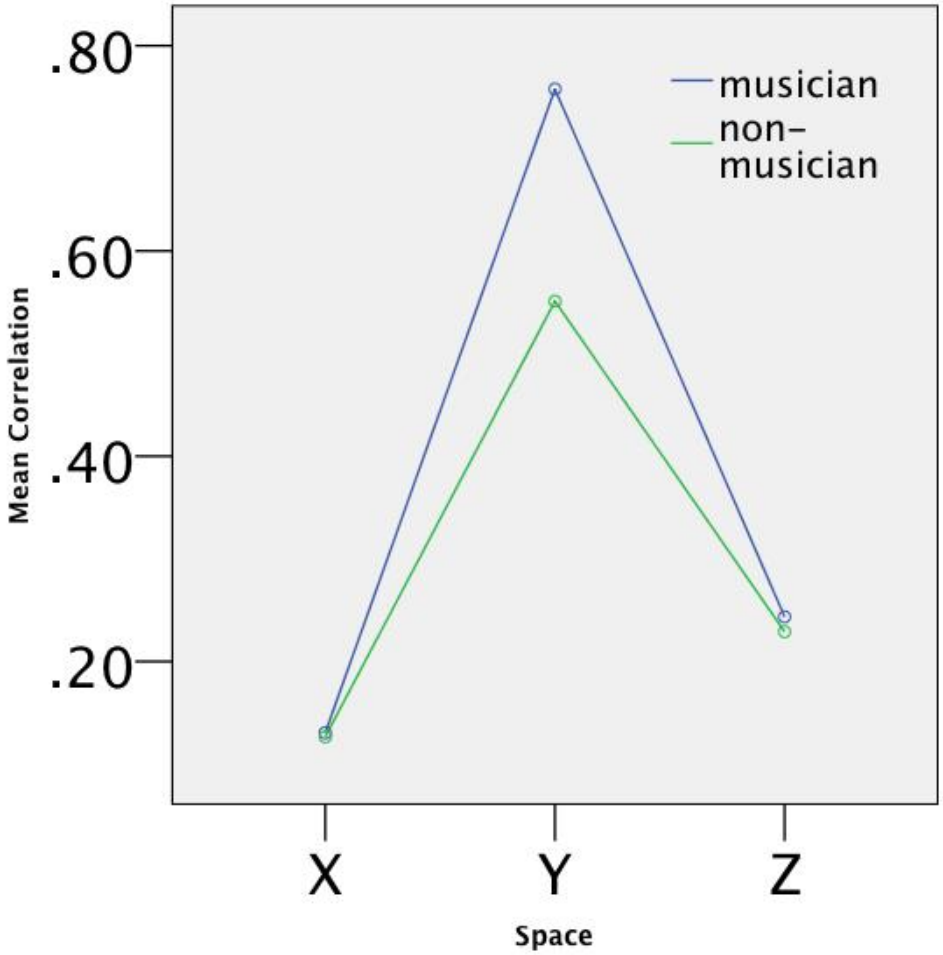
PITCH: main effect of ‘space’



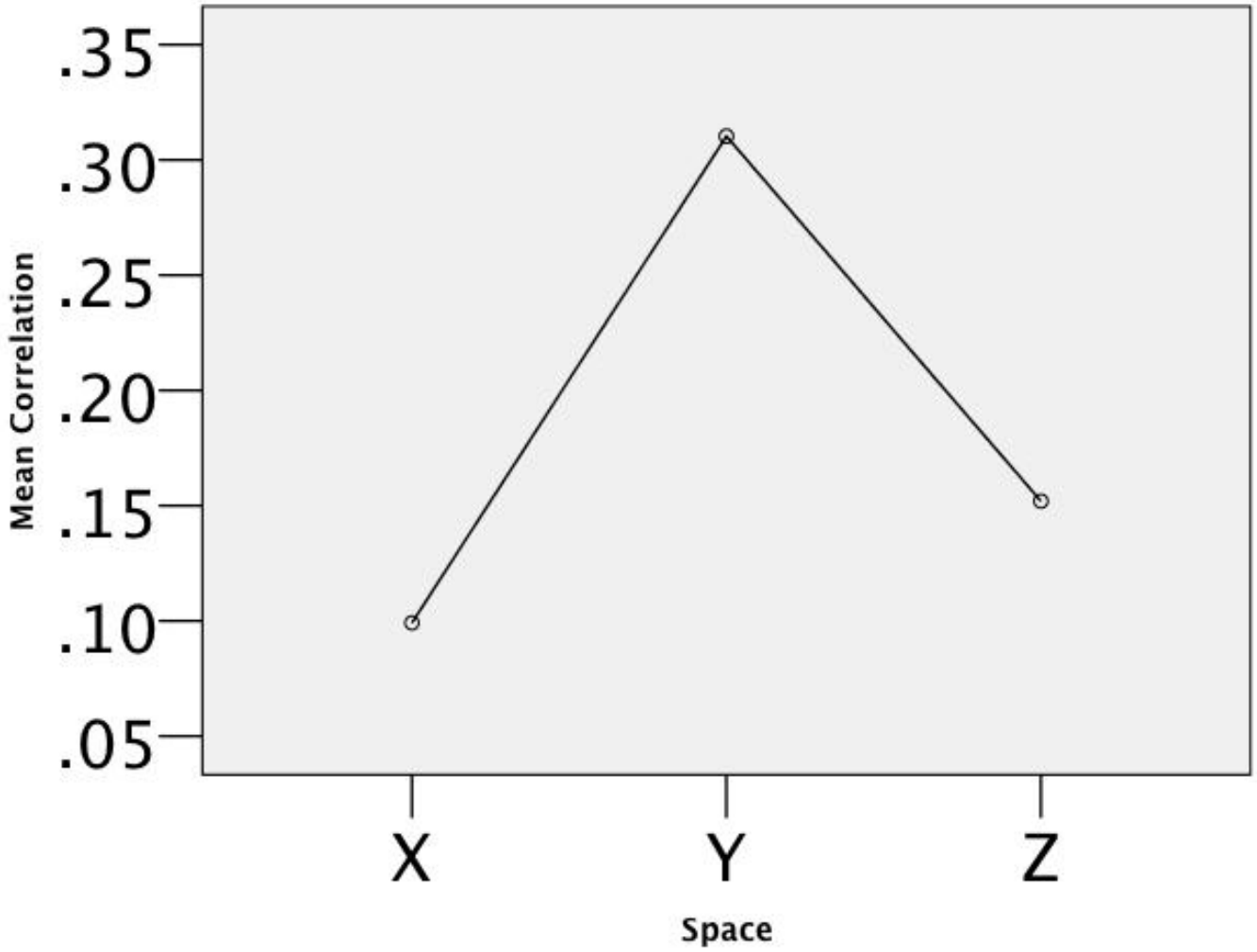
PITCH: **main effect of 'vision'**:
non-visual: M = .354 (SEM = .016)
visual: M = .325 (SEM = .015)

PITCH: **main effect of 'musician'**:
musician: M = .377 (SEM = .020)
non-mus: M = .302 (SEM = .020)

PITCH: interaction between 'space' and 'musician'

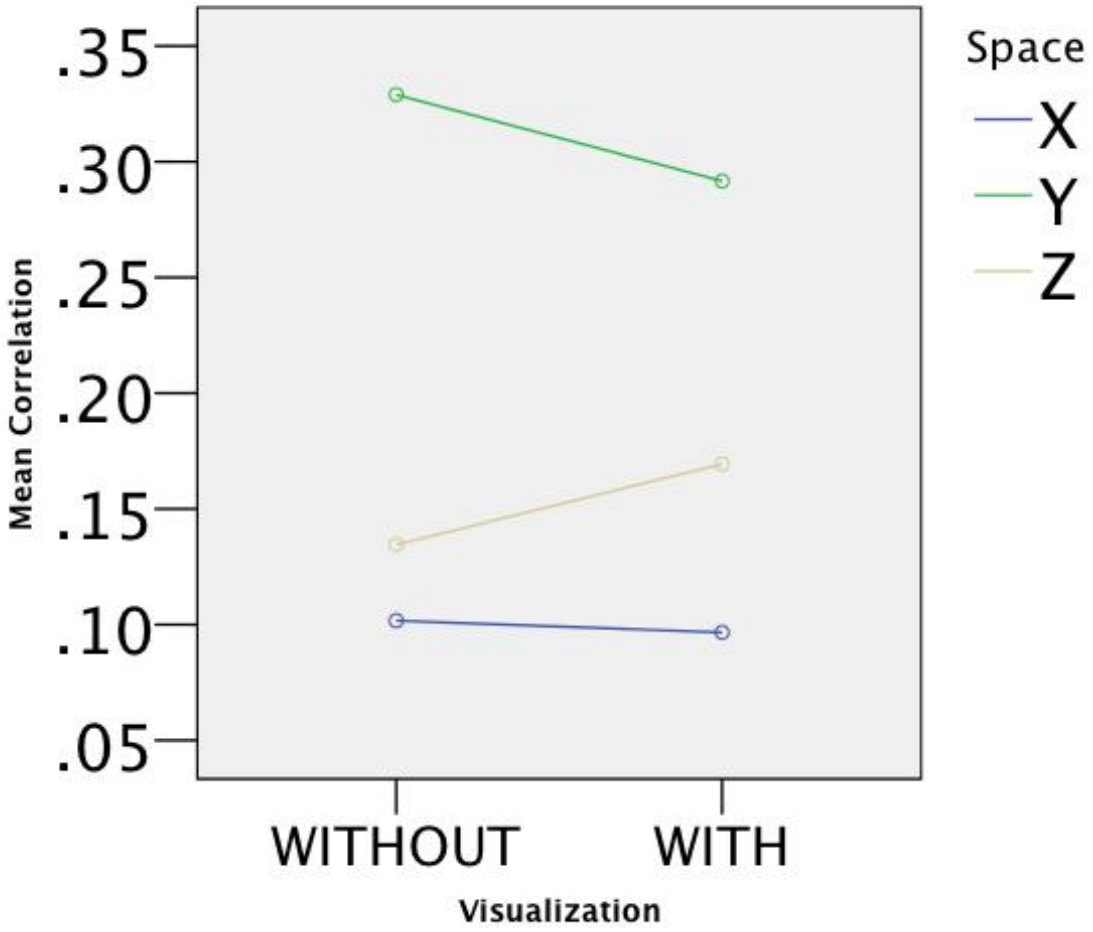


LOUDNESS: main effect of ‘space’



LOUDNESS: **main effect of 'musician'**:
musicians: M = .203 (SEM = .011)
non-musicians: M = .171 (SEM = .011)

LOUDNESS: interaction between 'vision' and 'space'



What was the **direction of movement** that participants used to represent (elapsed) time, pitch and loudness?

TIME: X-AXIS

Mean correlation between time and movement along the x-axis

			non-visual: negative (right to left)	non-visual: positive (left to right)
Musicians	visual	negative (right to left)	**3** nv: –.072 (.036) v: –.039 (.030)	**3** nv: .100 (.053) v: –.091 (.059)
		positive (left to right)	**3** nv: –.297 (.090) v: .783 (.105)	**23** nv: .628 (.367) v: .593 (.386)
Non-musicians	visual	negative (right to left)	**8** nv: –.310 (.275) v: –.292 (.206)	**4** nv: .370 (.356) v: –.082 (.065)
		positive (left to right)	**1** *nv: –.166 *v: .010	**19** nv: .586 (.336) v: .630 (.296)

PITCH: Y-AXIS

- ALL 64 PARTICIPANTS ACHIEVED POSITIVE CORRELATION COEFFICIENTS!
- Main effect of **'vision'** (M_{nv} = .679, M_{v} = .630)
- Main effect of **'musician'** (M_{mus} = .758, $M_{non\text{-}mus}$ = .551)

LOUDNESS: Y-AXIS

- All but 2 non-musicians (nv: –.001, v: –.061 // nv: .223, v: –.018) showed **positive correlations in both conditions**
- ANOVA with 32 musicians and 30 non-musicians revealed **significant main effect of 'vision'** (M_{nv} = .335, M_{v} = .299) and **'musician'** (M_{mus} = .341, $M_{non\text{-}mus}$ = .293)

LOUDNESS: Z-AXIS

Mean correlation between loudness and movement along the z-axis

			non-visual	
			negative (backwards)	positive (forwards)
Musicians	visual	negative (backwards)	**11** nv: –.158 (.149) v: –.143 (.119)	**3** nv: .042 (.026) v: –.102 (.037)
		positive (forwards)	**7** nv: –.128 (.057) v: .190 (.147)	**11** nv: .165 (.154) v: .218 (.140)
Non-musicians	visual	negative (backwards)	**16** nv: –.161 (.110) v: –.168 (.102)	**5** nv: .071 (.042) v: –.158 (.103)
		positive (forwards)	**7** nv: –.122 (.064) v: .138 (.140)	**4** nv: .062 (.052) v: .196 (.171)

Main findings

- Gestural representation of pitch is more consistent and stable (in terms of direction) than gestural representation of time or loudness
- Visual feedback of gestures triggers loudness representation on the z-axis
- Musicians represent pitch and loudness, but not elapsed time, more consistently with arm gestures compared to non-musicians

Limitations

- Participants were forced to use different dimensions for different musical characteristics (i.e. they couldn't use verticality for both pitch and loudness)
  - test musical parameters separately; however, in music they don't occur in isolation
- Forward movement resulted in larger disk
  - future studies should have two conditions (forward movement associated with larger **and** smaller disk size)

Conclusion

- Audio–visuo-spatial mappings with real (as opposed to imagined) bodily movements reveal a very strong association between pitch and height—one that is stronger for the group of musicians and stronger than e.g. between time and left-to-right movement—suggesting that even if pitch-height mappings prove innate, audio-visual correspondences are readily enhanced by cultural factors such as training.

Special thanks to…

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King's College London

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