Use of air conduction thresholds to predict bone conduction asymmetry and air-bone gap

Presented by:
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Project team:
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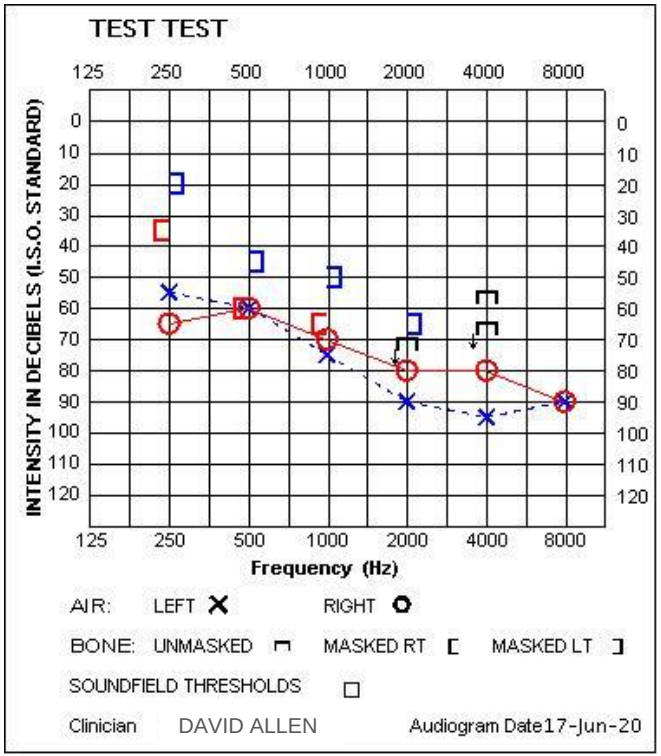
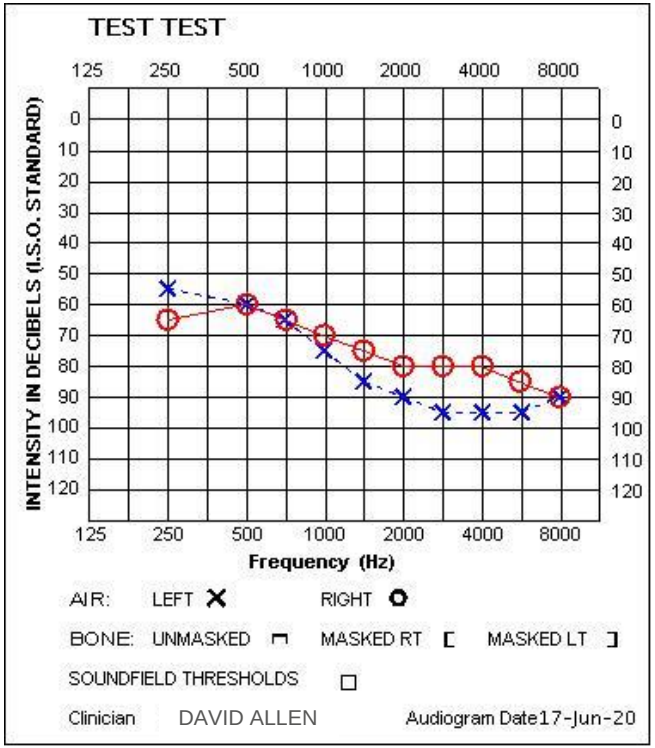
Traditionally we rely on bone conduction testing



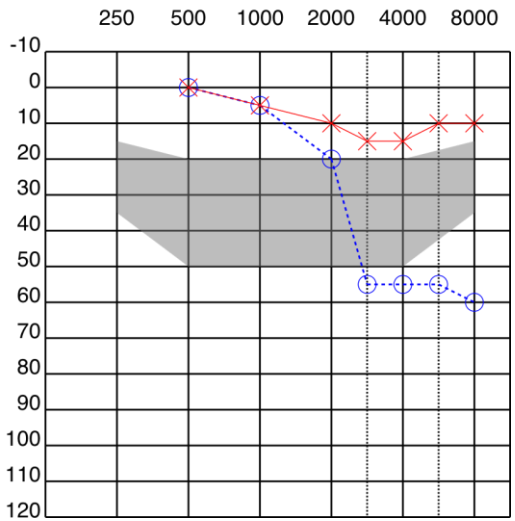
Bone conductor placement is difficult outside of the clinic

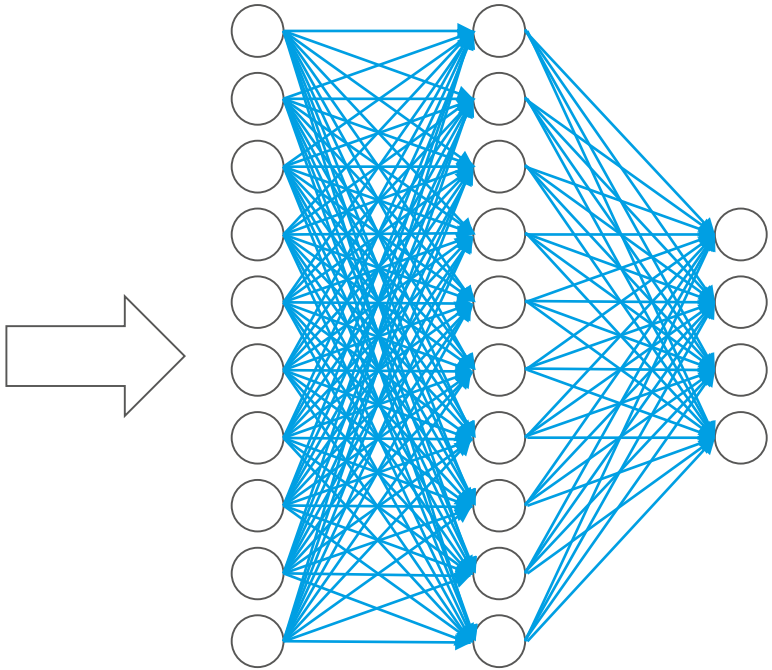
Air conduction testing is safe and easy

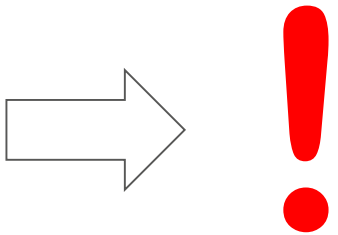
K Nearest Neighbours Imputation “Fills in the gaps”



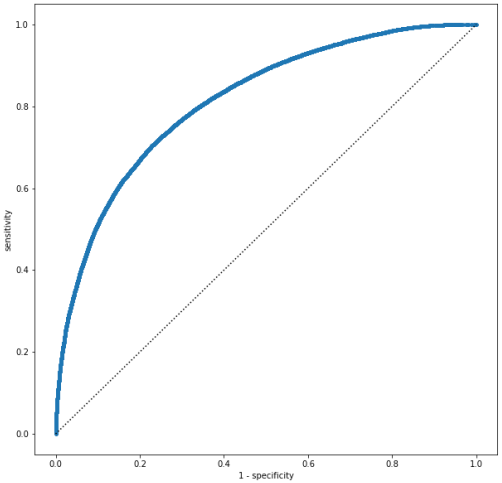
Neural network identifies patients requiring investigation



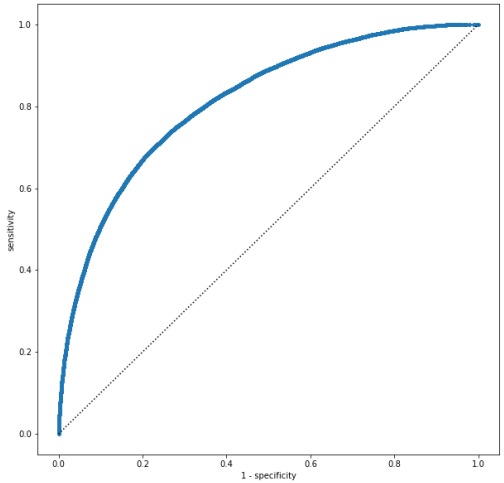




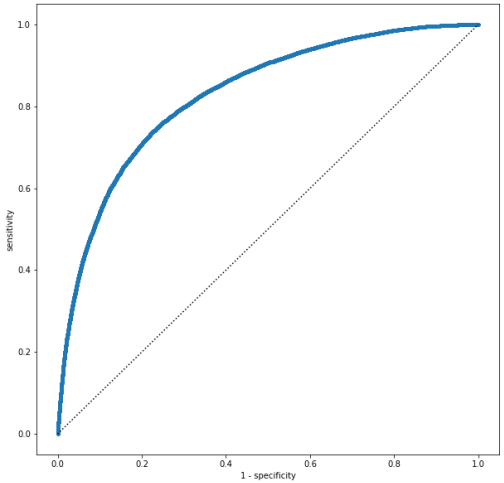
Reasonable sensitivity on test set



BC Asymmetry
AUC .831
Sensitivity 70.8%



Left Air-bone Gap
AUC .815
Sensitivity 67.1%



Right Air-bone Gap
AUC .815
Sensitivity 67.0%

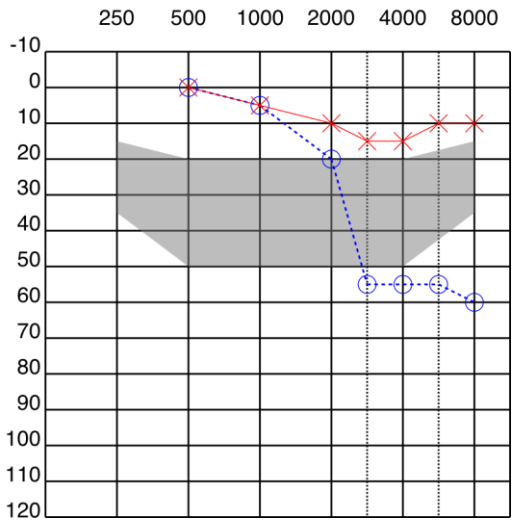
Fast response

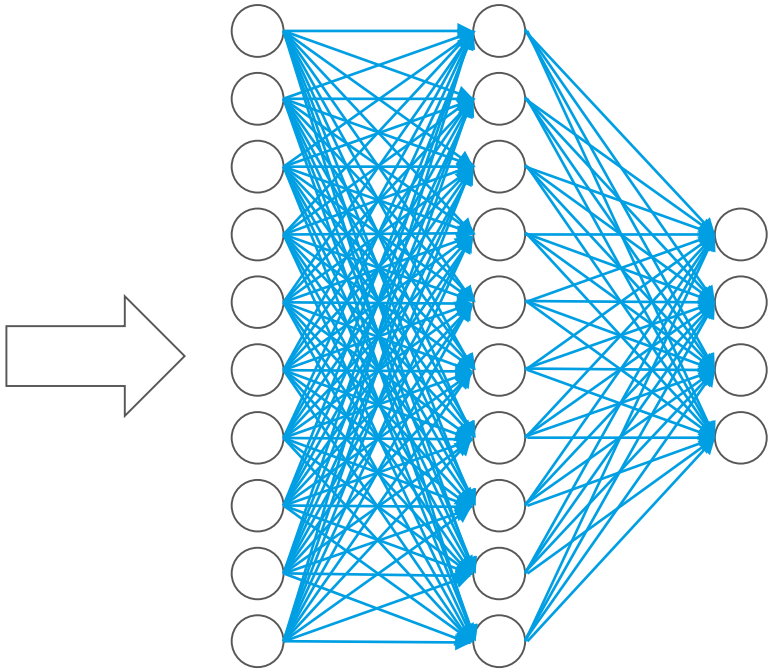
~7µsec /audiogram

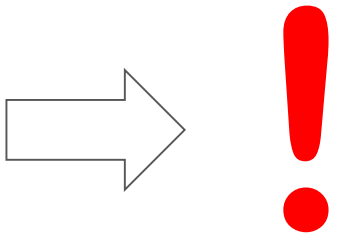
~18KB in memory

Higher accuracy with increasing severity

Automated tools can support clients and clinicians







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Aims

To explore the effectiveness of K-Nearest Neighbour Imputation in a large data set

To explore whether air conduction alone can predict findings traditionally requiring bone conduction

Our dataset

Most recent audiograms collected from patients seen at an Australian Government-owned hearing services organisation (n = 867,316)

Programmatic identification of Bone Conduction Asymmetry and Air-Bone Gap:

- BC Asymmetry: difference in BC of >15dB at one octave or >10dB at two adjacent octaves
- Air-Bone Gap: difference between AC and BC of >10dB at one octave

High rates of both observed – likely because a clinical sample, not population

	n	Mean age in years (SD)	% Male, % Female
No BCA or ABG	415,181	59 (29)	48, 51
Right ABG only	95,670	68 (26)	51, 48
Left ABG only	103,259	68 (25)	53, 46
Both Ears ABG	98,843	69 (25)	53, 46
BCA only	41,213	67 (20)	55, 45
Right ABG and BCA	31,974	70 (21)	51, 49
Left ABG and BCA	32,577	70 (21)	52, 47
Bilateral ABG and BCA	48,599	74 (20)	56, 44
Total	**867,316**	**65 (27)**	**50, 49**

K-Nearest Neighbours Imputation

Trained KNN Imputers on air conduction thresholds

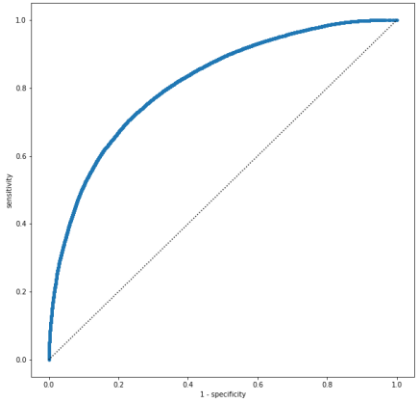
- Generated test set including penultimate audiograms (n = 365,367)
- Tuned k to minimise absolute error weighted by missingness
- Similar errors to previously reported in literature
- Much higher error on frequencies that are less frequently missing

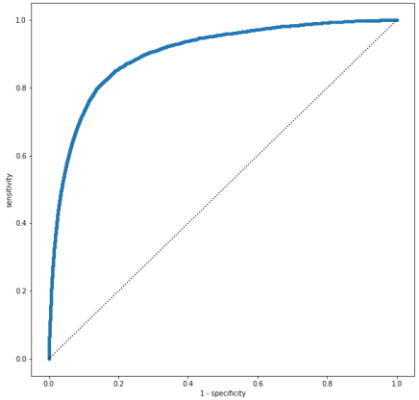
Threshold		N Missing (%)	Mean Deviation (SD)	MAD (SD)
Left Ear	250Hz	79150 (9.1)	-0.93 (7.58)	5.74 (5.04)
	500Hz	8522 (0.98)	-1.06 (8.03)	5.82 (5.62)
	750Hz	750431 (86)	0 (8.12)	5.89 (5.6)
	1kHz	3734 (0.43)	0.69 (13.06)	8.62 (9.83)
	1.5kHz	599097 (69)	0.26 (8.56)	6.19 (5.92)
	2kHz	9095 (1.0)	1.66 (8.99)	6.58 (6.34)
	3kHz	118854 (14)	0.32 (7.03)	5.01 (4.94)
	4kHz	5601 (0.65)	14.07 (18.07)	16.61 (15.77)
	6kHz	351987 (41)	0.27 (8.9)	6.59 (5.98)
	8kHz	81658 (9.4)	2.27 (11.31)	8.33 (7.97)
Right Ear	250Hz	78833 (9.1)	-0.14 (7.94)	5.77 (5.45)
	500Hz	8370 (0.97)	-1.07 (7.25)	5.55 (4.78)
	750Hz	749590 (86)	0.12 (7.87)	5.69 (5.44)
	1kHz	3551 (0.41)	1.12 (13.14)	8.69 (9.92)
	1.5kHz	613758 (71)	-0.2 (8.34)	5.95 (5.84)
	2kHz	9062 (1.0)	1.75 (8.77)	6.56 (6.08)
	3kHz	119220 (14)	0.49 (6.78)	5.11 (4.49)
	4kHz	5634 (0.65)	12.37 (16.94)	15.46 (14.17)
	6kHz	355188 (41)	0.66 (8.71)	6.74 (5.56)
	8kHz	81160 (9.4)	1.35 (10.87)	8.15 (7.32)

Neural Network Training

Split 867,316 audiograms into 90% training, 10% test

- Trained feed-forward neural network (two hidden layers, 50 neurons each)
- Selected threshold value with 80% specificity
- Similar accuracy across all three output features:
  - BC Asymmetry: AUC .831, Sensitivity 70.8%
  - Left Air-bone Gap: AUC .815, Sensitivity 67.1%
  - Right Air-bone Gap: AUC .815, Sensitivity 67.0%
- Higher accuracy for more severe Asymmetry/ABG (increase thresholds by 10):
  - BC Asymmetry: AUC .900, Sensitivity 85.6%
  - Left Air-bone Gap: AUC .898, Sensitivity 84.6%
  - Right Air-bone Gap: AUC .892, Sensitivity 83.3%





Summary

K-Nearest Neighbours Imputation can be used to accurately “fill in the gaps”

- However, very slow process – model-based clustering first may be helpful

Air conduction alone can be used to identify patients at high need of further investigation

- Accuracy is low for less severe findings
- May be helpful to pair with additional tools such as questionnaires

Important opportunity exists for screening patients using self-test or remote audiometry