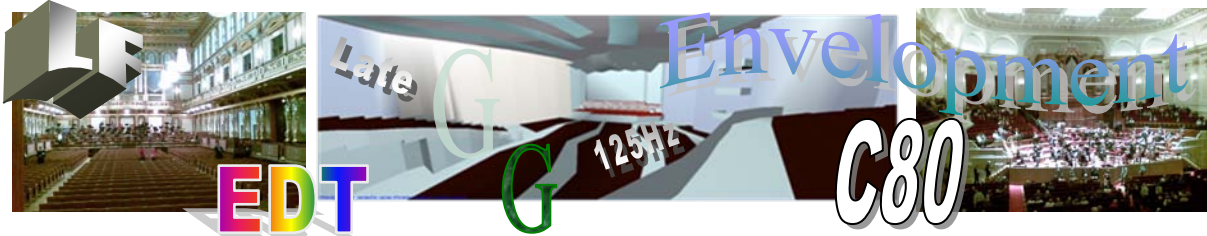


# Objective parameters – can they predict and explain subjective concert hall preference?

by M Skålevik, Brekke & Strand, Oslo, Norway, and [www.akutek.info](http://www.akutek.info)



**Status:** This poster presents status in a research project pursuing the problem expressed in the title above.

- Objective quality derived from hall-average parameter-values correlates well with subjective hall ranking
- However, quality “at listeners’ ears” deviates from hall-average, leaving results somewhat unexplained, Figure 1 (b)
- Sufficient **occupied** data only obtained indirectly, Table 2. Choice of method is critical, Figure 1
- Confident prediction of subjective preference only by method #2 (Table 2.), a hybrid combining **TVr** and **Odeon**
- LF is highly confusing; significant prediction can be achieved with the four parameters EDT, G, C and  $G_{late}$  alone
- Non-linear preference occurs. Linearity should be handled with care, compare Figure 3, Figure 4 and Figure 5

**Basis:** ISO 3382 suggests 5 listener aspects with corresponding objective parameters. Modifications: Envelopment described by late G, instead of late lateral G; Low frequency level parameter added, Table 1. Beranek (2003): Subjective rank ordering of 58 concert halls includes 10 halls for which we have 126 detailed measurements by Gade (1989) and corresponding simulated measurements in Odeon prediction software.

**Table 1** Aspects and parameters studied in the project

Reverberance	EDT	s
Perceived Sound level	G	dB
Perceived Clarity	C	dB
Apparent Source Width	LF	1
Listener Envelopment	$G_{late}$	dB
Low frequency level	$G_{125Hz}$	dB

**Scope:** (a) Evaluate correlation between objective data (measured and calculated) and Beranek’s subjective data. (b) Test for statistically significant distinction between data from halls of subjectively distinct quality classes A, B and C (34, 22 and 60 measurements, respectively) according to Beranek.

**TVr-predictions:** Predictions of parameters from reverberation time **T**, room volume **V**, and source-receiver distance **r**, based on Barron Revised Theory, (Skålevik 2010).

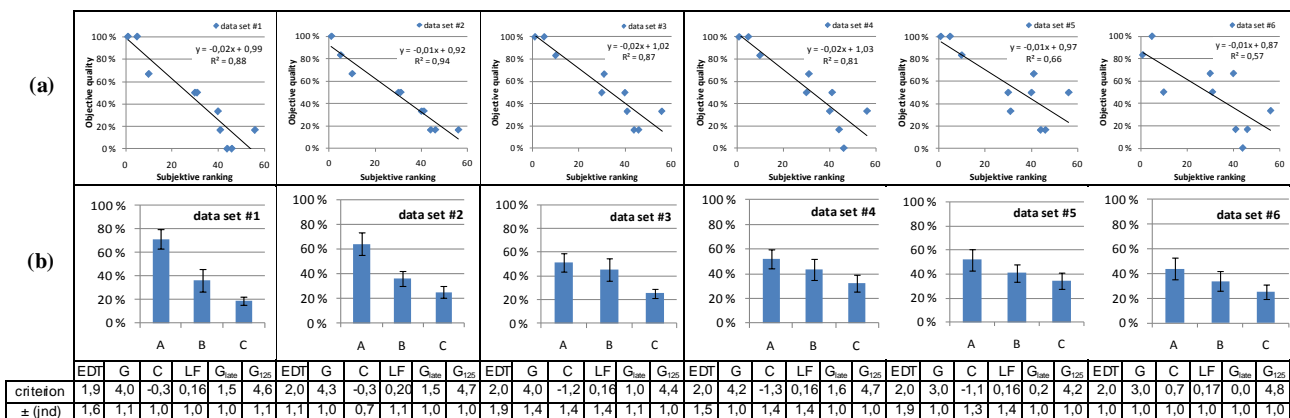
**Data “at listeners ears” in occupied condition:** For each position, data is obtained in 6 different ways, Table 2.

**Table 2** Six objective, “occupied” data sets, obtained by different methods, to be tested for correlation with subjective data;  $R^2$  example.

#1	TVr-predictions of G, EDT, C, $G_{late}$ and $G_{125}$ ; LF measured by Gade. Occupied T from Beranek.	$R^2=0.88$
#2	TVr-predictions of G, EDT, C, $G_{late}$ and $G_{125}$ ; LF and T simulated in Odeon.	$R^2=0.94$
#3	Unoccupied data by Gade, corrected to “occupied” by TVr-differences with T-data from Beranek	$R^2=0.87$
#4	Unoccupied data by Gade, corrected to “occupied” by TVr-differences with T simulated in Odeon	$R^2=0.81$
#5	Unoccupied data by Gade, corrected to “occupied” by differences simulated in Odeon	$R^2=0.66$
#6	All parameters simulated in Odeon	$R^2=0.57$

**Procedure:** For each parameter (Table 1) a criteria value and a tolerance (in JND) is suggested, by which all 126 positions are evaluated. Each position is rewarded by one point for each parameter satisfying its criteria.

**Some results:** 2x6 diagrams below, Figure 1, columns are the 6 data sets. Upper row (a): Objective quality (%) of 10 halls plotted against Beranek’s subjective ranking, after letting the criterion (here: hall-average value  $\pm$  tolerance) for each parameter, vary by trial-and-error until maximum  $R^2$  is obtained. 100% quality means that all parameters in the hall meet their given criteria. Lower row (b): Quality in seats in halls of class A, B and C. Average quality and 95% confidence intervals indicate that, using G, EDT, C, LF,  $G_{late}$  and  $G_{125Hz}$ , only data sets #1 and #2 show significant distinction in objective quality between A, B and C.



**Figure 1**

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Example: Data set #1

Table 3, process input data: TVr-predicted parameters, except LF measured by Gade, based on occupied T-data from Beranek.

Table 4, process output data: Overall objective quality in %; Correlation  $r^2=0.88$  and qualifying value and tolerance (jnd) for each parameter.

**Table 3**

		Parameter	EDT	G	C	LF	G,Late	G125
Beranek's ranking		Qualifying criteria	<b>1,9</b>	<b>4,0</b>	<b>-0,3</b>	<b>0,16</b>	<b>1,5</b>	<b>4,6</b>
Class	No	Tolerance (JND)	1,6	1,1	1	1	1	1,1
A high	1	Musikverein, Vienna	1,9	4,9	-0,2	0,16	2,0	5,6
	5	Concertgebouw, Amsterdam	1,8	4,2	0,2	0,16	1,1	4,7
	10	St David, Cardiff	1,9	2,9	-0,1	0,18	-0,1	2,7
B Medium	30	Gasteig, Munich	1,8	1,7	0,5	0,11	-1,7	1,7
	30	Konserthus, Gøteborg	1,6	4,4	0,7	0,09	1,1	5,9
C low	40	Festspielhaus, Salzburg	1,4	2,8	1,5	0,18	-1,0	3,6
	41	Liederhalle, Stuttgart	1,5	2,2	0,8	0,15	-1,2	2,2
	44	Usher, Edinburg	1,2	0,8	2,5	0,23	-3,6	2,2
	46	Royal Festival Hall, London	1,3	0,8	1,9	0,24	-3,3	1,9
	56	Barbican, London	1,6	2,5	0,9	0,17	-1,0	1,9

**Table 4**

		Parameter	EDT	G	C	LF	G,Late	G125	overall objective quality
Beranek's ranking		Qualifying criteria	<b>1,9</b>	<b>4,0</b>	<b>-0,3</b>	<b>0,16</b>	<b>1,5</b>	<b>4,6</b>	
Class	No	Tolerance (JND)	1,6	1,1	1	1	1	1,1	
A high	1	Musikverein, Vienna	92 %	67 %	92 %	75 %	83 %	58 %	78 %
	5	Concertgebouw, Amsterdam	90 %	80 %	90 %	70 %	70 %	80 %	80 %
	10	St David, Cardiff	100 %	50 %	92 %	58 %	25 %	25 %	58 %
B Medium	30	Gasteig, Munich	75 %	0 %	75 %	33 %	0 %	0 %	31 %
	30	Konserthus, Gøteborg	0 %	60 %	70 %	20 %	60 %	50 %	43 %
C low	40	Festspielhaus, Salzburg	0 %	40 %	0 %	30 %	0 %	60 %	22 %
	41	Liederhalle, Stuttgart	0 %	17 %	67 %	33 %	8 %	17 %	24 %
	44	Usher, Edinburg	0 %	7 %	0 %	36 %	0 %	14 %	10 %
	46	Royal Festival Hall, London	0 %	20 %	0 %	20 %	0 %	20 %	10 %
	56	Barbican, London	0 %	29 %	57 %	71 %	7 %	14 %	30 %
		average	36 %	37 %	54 %	45 %	25 %	34 %	

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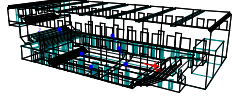
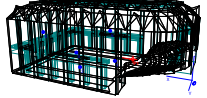
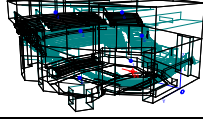
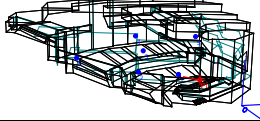
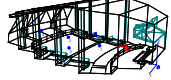
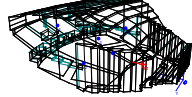
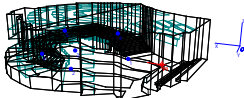
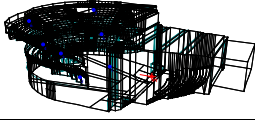
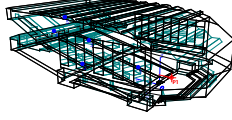
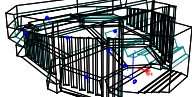
Concert hall	Volume m <sup>3</sup>	RT occ (s)	Beranek Ranking	Odeon Model
Musikverein, Vienna	15000	2,0	1	
Concertgebouw, Amsterdam	19000	2,0	5	
St David, Cardiff	22000	2,0	10	
Gasteig, Munich	30000	1,9	19-39	
Konserthus, Gøteborg	12000	1,6	19-39	
Festspielhaus, Salzburg	15500	1,5	40	
Liederhalle, Stuttgart	16000	1,6	41	
Usher Hall, Edinburg	16000	1,3	44	
Royal Festival Hall, London	22000	1,5	46	
Barbican, London	18000	1,7	56	

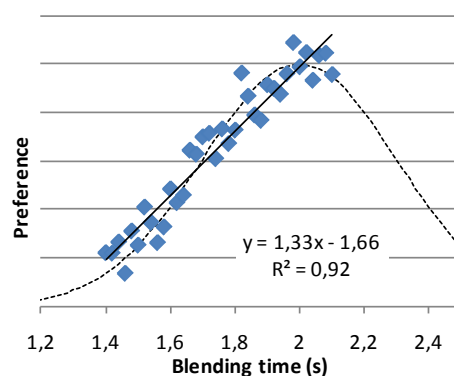
Figure 2 The ten halls

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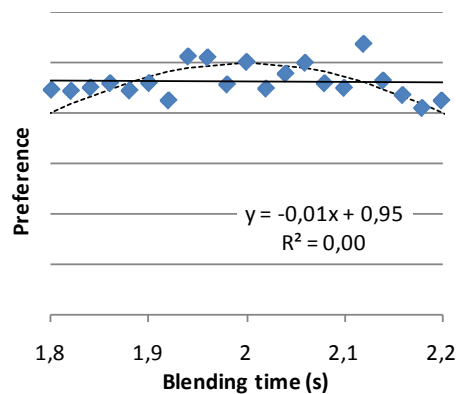
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## Caveats and pitfalls

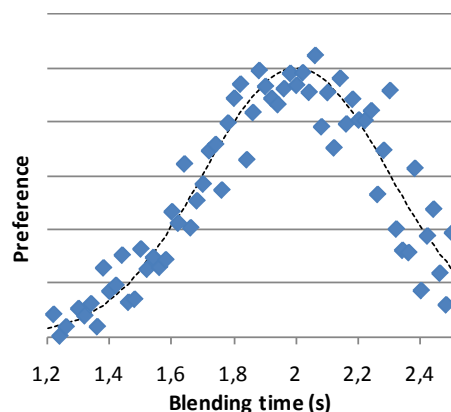
- Beware of Orthogonality, Linear Regression, and Multiple Linear Regression
- Non-linear preference: Optimum values, not "The more – the better"



**Figure 3** Plot of Preference vs Blending Time, and a linear trend found by researcher A.



**Figure 4.** Plot of Preference vs Blending Time, found by researcher B.



**Figure 5** Plot of Preference vs BT, found by researcher C to best fit a Gauss-curve with  $\mu=2.0s$  and  $\sigma=0.3s$