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https://doi.org/10.1097/AUD.0000000000001101

Supplementary Digital Content 7

Relationship between age and binaural utility

(This document is supplementary to the paper by Summerfield, Kitterick, and Goman entitled 'Development and critical evaluation of a condition-specific preference-based measure sensitive to binaural hearing in adults: the York Binaural Hearing-related Quality of Life System'.)

1. Introduction

1.1. This supplementary digital content describes analyses of the relationship between the age of informants and the utilities which they assigned using the time trade-off method in Phase 1 of the study.

1.2. Dolan and Roberts (2002) reported a systematic association between age and time trade-off valuations when a population-representative sample of adult informants valued health states from the EuroQol Descriptive System using a 10-year time frame. The number of years traded declined as the age of informants increased up to 45 years, then increased gradually to 70 years and more abruptly above that age. As a result, values of health utility would have described a function of age shaped like an inverted U. We examined whether a similar relationship is found between binaural utility and age. We then addressed two questions. First, if a relationship exists, can it account for the difference in overall utility between students and non-students? Second, does the search for a relationship establish grounds for preferring values of binaural utility estimated with the 10-year time frame in Experiments 1a and 1b or the 50-year time frame in the Pilot Experiment (Supplementary Digital Content 5)?

1.3. We conducted a sequence of four analyses. The dependent variable in each analysis was *overall utility*; i.e. the average of the 27 values of binaural utility provided by each participant. The first analysis included participants from all three experiments (Pilot, 1a, 1b). The second analysis included participants from the Pilot Experiment only. The third analysis included participants from Experiment 1a and all participants from Experiment 1b (i.e. those instructed to imagine that their vision was perfect and those instructed to imagine that their vision was impaired). The fourth analysis included participants from Experiment 1a and only those participants from Experiment 1b who were instructed to imagine that their vision was perfect; these are the participants whose data are reported in the paper and from whom the valuation set for the YBHRQL was derived.

1.4. For reference, Table 1 lists the numbers of participants in each experiment and Table 2 lists the number of those participants who were included in each analysis.

2. Analysis 1: Experiments 1a, 1b, and the Pilot Experiment

2.1. Figure 1A displays individual values of overall utility plotted against age for the participants in the Pilot Experiment and Experiments 1a and 1b. Values from non-students are plotted as open circles and values from students as filled circles. A quadratic function, fitted to the data from non-students without regard to time frame or vision, accounted for a small but significant proportion of the variance in average hearing utility ($F_{(2,293)} = 8.092$, $p < .001$, adjusted R square = .046). The continuous curved line in Figure 3A plots the function. Its equation is: *Average utility* = .586 + (.0119 x *Age*) - (.000116 x Age^2) (Eqn. 1), where *Age* is the age of the participant in years.

2.2. Figure 1B demonstrates the fit of this function to the data. The open circles plot the mean value of average hearing utility for subsets of the non-students grouped by age in 10-year bands: 21-30, 31-40, 41-50, 51-60, 61-70, 71+ years. Each open circle has been plotted against the average age of the subgroup on the horizontal axis. The continuous curved line in Figure 1B is the fitted quadratic function (Eqn. 1). It fits the data adequately insofar as it intersects the 95% confidence interval of each mean value of average hearing utility.

2.3. The two filled data points in Figure 1B plot mean values of average hearing utility for students grouped by age in two bands: 18-20 and 21+ years. The function fitted to the data from non-students (Eqn. 1) also intersects the 95% confidence intervals of each of these mean values of average hearing utility. The function changes only minimally if it is fitted to the data from non-students and students combined. This second function (Eqn. 2) is plotted by the dashed line in Figure 1B. Its equation is: *Average Utility* = .571 + (.0122 x *Age*) - (.000117 x Age^2) (Eqn. 2). Each parameter in this equation is closely similar in value to the corresponding parameter in Eqn. 1. The result is compatible with the idea that the differences in average utility between students and non-students can be accounted for primarily by the difference in their ages.

2.4. That account was tested by predicting overall utility from a linear weighted combination of the variables *Gender* (female, male), *Time frame* (10 years, 50 years), *Group* (student, non-student), *Vision* (perfect, impaired), and the covariates *Age* and Age^2. Significant components of the variance were explained by *Age* ($F_{(1,530)}$ = 11.206, p < .01, η_p^2 = .021), Age^2 ($F_{(1,530)}$ = 9.001, p < .01, η_p^2 = .017), *Time frame* ($F_{(1,530)}$ = 99.814, p < .001, η_p^2 = .158), and *Vision* ($F_{(1,530)}$ = 64.884, p < .001, η_p^2 = .109), but neither by *Gender* ($F_{(1,530)}$ = .398, p = .529, η_p^2 = .001), nor, critically, by *Group* ($F_{(1,530)}$ = 1.324, p = .250, η_p^2 = .002).

2.5. These results were obtained when data from Experiments 1a, 1b, and the Pilot Experiment were pooled. In the following sections, we consider whether the main result – that differences in overall utility between students and non-students can be accounted for primarily by the difference in their ages – holds both for data obtained with the 50-year time frame in the Pilot Experiment and for data obtained with the 10-year time frame in Experiments 1a and 1b.

3. Analysis 2: Pilot Experiment

3.1. Figure 2A plots values of average utility against age for individual participants in the Pilot Experiment. Open circles plot data for non-students. Filled circles plot data for students. Linear and quadratic functions were fitted to the data from non-students. Neither function was a good fit (Linear: $F_{(1,153)}$ = 3.213, p = .075; Quadratic: $F_{(2,152)}$ = 2.166, p = .118). The straight line in Figure 2A is the linear function. It is re-plotted as the continuous straight line in Figure 2B. Despite describing a non-significant increase in average hearing utility with age, it intersects the 95% confidence limits of the mean value of average hearing utility for each age group, including the two groups of students. However, it differs noticeably from the linear function which best fits the data from non-students and students together ($F_{(1,248)}$ = 19.525, p<.001) which is plotted as the dashed line in Figure 2B.

3.2. As a further test, we sought to predict overall utility from a linear weighted combination of the variables *Gender* (female, male), *Group* (student, non-student), and the covariates *Age* and Age^2. None of the variables explained a significant component of the variance: *Age* ($F_{(1,244)}$ = .445, p = .505, η_p^2 = .002), Age^2 ($F_{(1,244)}$ = .975, p = .324, η_p^2 = .004), *Gender* ($F_{(1,244)}$ = 1.153, p = .284, η_p^2 = .005), and *Group* ($F_{(1,244)}$ = 3.169, p = .076, η_p^2 = .013).

3.3. In summary, values of overall utility elicited with the 50-year time frame in the Pilot Experiment do not describe a function of age shaped like an inverted U. Overall utility does not increase significantly with age among non-students, and a linear function fitted to the data of non-students does not include the data from students convincingly. That result suggests that differences between non-students and students, in addition to the difference in their ages, may underlie the difference in their values of binaural utility estimated with the 50-year time frame.

4. Analysis 3: Experiment 1a and all participants from Experiment 1b

4.1. Analysis 3 included the participants from Experiment 1a and all participants from Experiment 1b, both those who were instructed to imagine that their vision was perfect and those instructed to imagine that their vision was impaired. Figure 3 shows data and curve fits in the same format as Figures 1 and 2. A quadratic function was a better fit to the data for non-students ($F_{(2,138)}$ = 6.618, p < .01) than was a linear function ($F_{(1,138}$= 1.041, p = .309). The quadratic function is plotted as the continuous line in Panels A and B of Figure 3. Its equation is: *Average utility* = .435 + (.0150 x *Age*) - (.000142 x Age^2) (Eqn. 3). It intersects the 95% confidence interval of the mean value of hearing utility for each age group, including the two groups of students. This function is closely similar to the quadratic function that best fits the data from non-students and students together. Its equation is: *Average utility* = .466 + (.0138 x *Age*) - (.000131 x Age^2) (Eqn. 4) which is plotted as the dashed line in Panel B. The result is compatible with the conclusion that the difference in binaural utility between students and non-students is primarily a reflection of the difference in the ages.

4.2. That account was tested by predicting overall utility from a linear weighted combination of the variables *Gender* (female, male), *Group* (student, non-student), *Vision* (perfect, impaired), and the covariates *Age* and Age^2. Significant components of the variance were explained by *Age* ($F_{(1,284)}$ = 12.793, p < .001, η_p^2 = .043), Age^2 ($F_{(1,284)}$ = 11.275, p < .01, η_p^2 = .038), and *Vision* ($F_{(1,284)}$ = 43.647, p < .001, η_p^2 = .133), but neither by *Gender* ($F_{(1,284)}$ = .554, p = .457, η_p^2 = .002), nor by *Group* ($F_{(1,284)}$ = .081, p = .776, η_p^2 = .000).

5. Analysis 4: Experiment 1a and perfect-vision participants from Experiment 1b

5.1. Analysis 4 included the participants from Experiment 1a and those participants from Experiment 1b who were instructed to imagine that their vision was perfect. Figure 4 shows the data and curve fits in the same format as Figures 1-3. A quadratic function was a better fit to the data for non-students ($F_{(2,93)}$ = 8.397, p < .001) than was a linear function ($F_{(1,94}$= 1.672, p = .199). The quadratic function is plotted as the continuous line in Panels A and B of Figure 4. Its equation is: *Average utility* = .386 + (.0178 x *Age*) - (.000165 x Age^2) (Eqn. 5). It intersects the 95% confidence interval of the mean value of hearing utility for each age group of non-students and for one of the two groups of students. This function is loosely similar to the quadratic function that best fits the data from non-students and students together. Its equation is: *Average utility* = .530 + (.0125 x *Age*) - (.000119 x Age^2) (Eqn. 6) which is plotted as the dashed line in Panel B.

5.2. The similarity of the two quadratic functions in Figure 4B is less striking that the similarity of the corresponding functions in Figures 1B and 3B. This may be a consequence of the reduced number of non-students in Analysis 4 compared with Analyses 1 and 3. Nonetheless, given the results of the previous analyses, we judged that there was sufficient similarity between the functions to justify the conclusion that the difference in binaural utility between students and non-students is primarily a reflection of the difference in the ages.

5.3. That account was tested by predicting overall utility from a linear weighted combination of the variables *Gender* (female, male), *Group* (student, non-student), and the covariates *Age* and Age^2. Significant components of the variance were explained by *Age* ($F_{(1,197)}$ = 12.152, p

< .01, η_p^2 = .058) and *Age²* ($F_{(1,197)}$ = 10.959, p < .01, η_p^2 = .053), but neither by *Gender* ($F_{(1,197)}$ = .456, p = .500, η_p^2 = .002), nor by *Group* ($F_{(1,197)}$ = .677, p = .412, η_p^2 = .003).

6. Discussion

6.1. The main result of these analyses is the demonstration of a more compelling relationship between age and overall utility when valuations were obtained with the 10-year time frame in Experiments 1a and 1b than with the 50-year time frame in the Pilot Experiment. In turn, that result provides stronger support for the idea that the difference in hearing utility between students and non-students obtained with the 10-year time frame related primarily to the difference in their ages, rather to other differences between the groups. The result justifies the strategy of combining data obtained with the 10-year time frame from students and non-students after age-standardizing their valuations. That consideration, together with the recommendation by NICE that time trade-off valuations should use a 10-year time frame, underpinned the decision to derive a value set for the YBHRQL from Experiments 1a and 1b rather than the Pilot Experiment, despite a larger number of informants having participated in the Pilot Experiment.

6.2. There are two subsidiary issues. First, why did participants trade proportionately fewer years with the 50-year than the 10-year time frame? Second, why did the two time frames yield different relationships between overall utility and age? In theory, values obtained with the time trade-off method using different time frames might be expected to display constant proportionality; that is, the years traded to alleviate a condition would be a constant proportion of the time frame. However, reviews (Dolan and Stalmeier 2003; Attema and Brouwer 2010) have noted that, in practice, constant proportionality has been found in some studies but not in others, with longer time frames associated with both proportionately more, and proportionately fewer, years traded in different studies.

6.3. There is no guidance, therefore, to explain why proportionately fewer years were traded with the 50-year time frame than the 10-year time frame in Experiment 1. Any or all of several differences between the two implementations of the time trade-off method may have contributed. With the 50-year time frame, informants indicated *the number of years they would give up* to be free of the problems described in each scenario; with the 10-year time frame, they indicated *the number of years living with no problems that would be equivalent* to living 10 years with the problems. With the 50-year time frame, informants conveyed their judgment by *writing down a number*; with the 10-year time frame, they *made a mark on a visual-analogue scale*. With the 50-year time frame, they were instructed to imagine that *they were 30 years old with a further 50 years to live*; with the 10-year time frame, they were instructed to consider that *they were their actual age with a further 10 years to live*.

6.4. In the absence of a systematic debrief of each informant, we can only speculate about why valuations varied with age in different ways with the two time frames. It is plausible that the willingness to trade declines as caring responsibilities build up into middle age, but then increases as those responsibilities reduce in older age. That was the pattern shown with the 10-year time frame in Experiments 1a and 1b and in the study reported by Dolan and Roberts (2002). Why then was the pattern not also shown with the 50-year time frame? Possibly, despite the instruction to imagine that they were 30 years old, informants found it difficult to ignore their current age and, in particular, were reluctant to give up years that they had already lived. Certainly, the time trade-off task entailed greater conceptual complexity with the 50-year time frame than with the 10-year time frame.

7. References

Attema, A.E., Brouwer, W.B.F. (2010). On the (not so) constant proportional trade-off in TTO. *Quality of Life Research, 19*, 489-497.

Dolan, P., Roberts, J. (2002). To what extent can we explain time trade-off values from other information about respondents? *Social Science & Medicine, 54,* 919-929.

Dolan, P., Stalmeier, P. (2003). The validity of time trade-off values in calculating QALYs: Constant proportional time trade-off versus the proportional heuristic. *Journal of Health Economics, 22,* 445-458.

Table 1 Numbers (N) and age of participants in each experiment

Experiment	Group	Participants (N)	Inconsistent traders (N)	Zero traders (N)	Included in analyses (N)	Minimum age (years)	Mean age (years)	Maximum age (years)	% female
Pilot	Students	95	0	2	95	18	20.3	25	77.9
	Non-students [Public]	104	0	16	104	22	47.7	79	53.8
	Non-students [Clinicians]	51	0	10	51	23	45.1	62	86.3
1a	Students	59	0	0	59	18	20.8	26	79.7
	Non-students [Public]	52	1	4	51	22	44.1	64	52.9
1b	Students [Perfect vision]	48	0	0	48	18	20.7	26	60.9
	Students [Impaired vision]	48	2	0	46	19	20.3	22	58.3
	Non-students [Public] [Perfect vision]	48	3	5	45	18	49.1	80	57.8
	Non-students [Public] [Impaired vision]	48	3	1	45	22	50.1	90	60.0

Table 2 Numbers (N) of participants included in each analysis

Analysis	Experiments	Group	Included in analysis (N)
1	Pilot, 1a, 1b	Students	248
		Non-students	296
		Total	544
2	Pilot	Students	95
		Non-students	155
		Total	250
3	1a, 1b (perfect and impaired vision)	Students	153
		Non-students	141
		Total	294
4	1a, 1b (perfect vision only)	Students	107
		Non-students	96
		Total	203

Figure 1 Analysis 1: In Panel A, overall utility is plotted against age for individual participants in Experiments 1a, 1b, and the Pilot Experiment. Filled circles, students; open circles, non-students. Continuous line plots the quadratic function that best fits the data of non-students. In Panel B, overall utility with 95% confidence intervals is plotted for participants grouped by age in 10-year ranges plotted against the average age of the group. Filled circles, students; open circles, non-students. Continuous line is the quadratic function from Panel A that was fitted to the data from non-students. Dashed line is the quadratic function that best fits the data from non-students and students together.

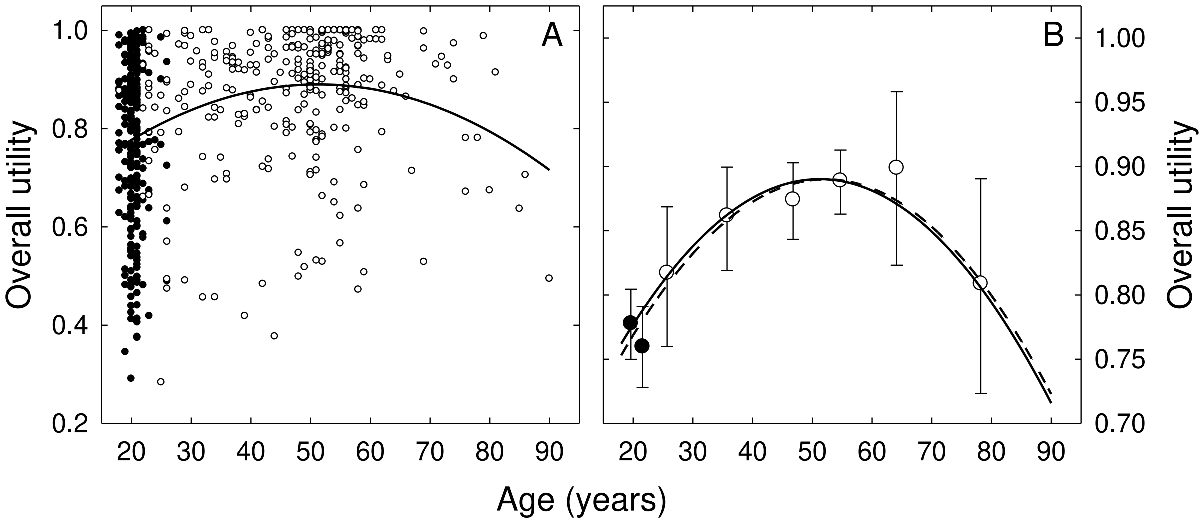

Figure 2 Analysis 2: In Panel A, overall utility is plotted against age for individual participants in the Pilot Experiment. Filled circles, students; open circles, non-students. Continuous line plots the linear function that best fits the data of non-students. In Panel B, overall utility is plotted with 95% confidence intervals for participants grouped by age in 10-year ranges plotted against the average age of the group. Filled circles, students; open circles, non-students. Continuous line is the linear function from Panel A. Dashed line is the linear function that best fits the data from non-students and students together.

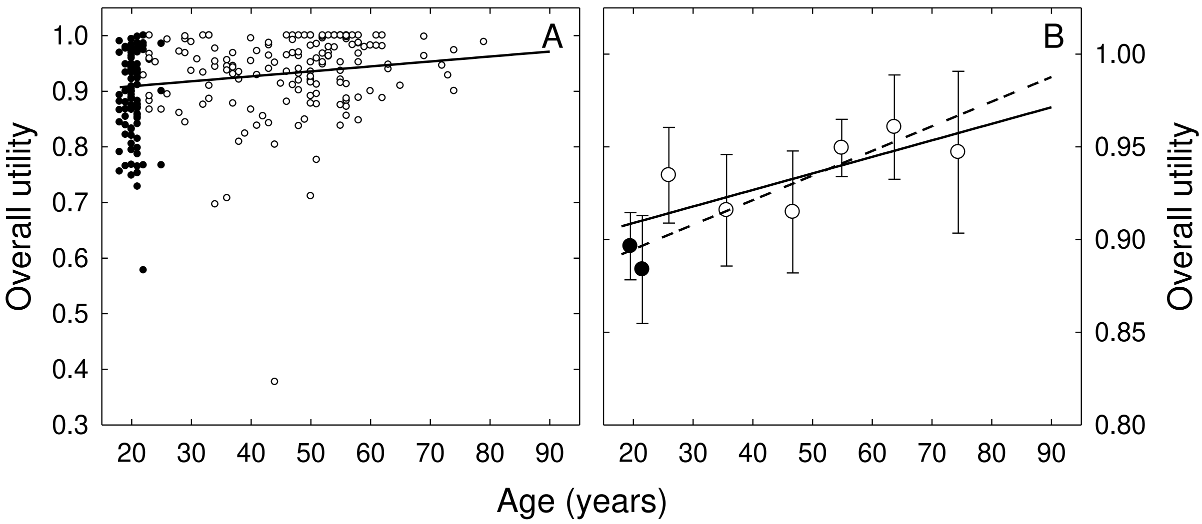

Figure 3 Analysis 3: In Panel A, overall utility is plotted against age for individual participants in Experiment 1a and for all participants in Experiment 1b. Filled circles, students; open circles, non-students. Continuous line plots the quadratic function that best fits the data of non-students. In Panel B, overall utility is plotted with 95% confidence intervals for participants grouped by age in 10-year ranges plotted against the average age of the group. Filled circles, students; open circles, non-students. Continuous line is the quadratic function from Panel A. Dashed line is the quadratic function that best fits the data from non-students and students together.

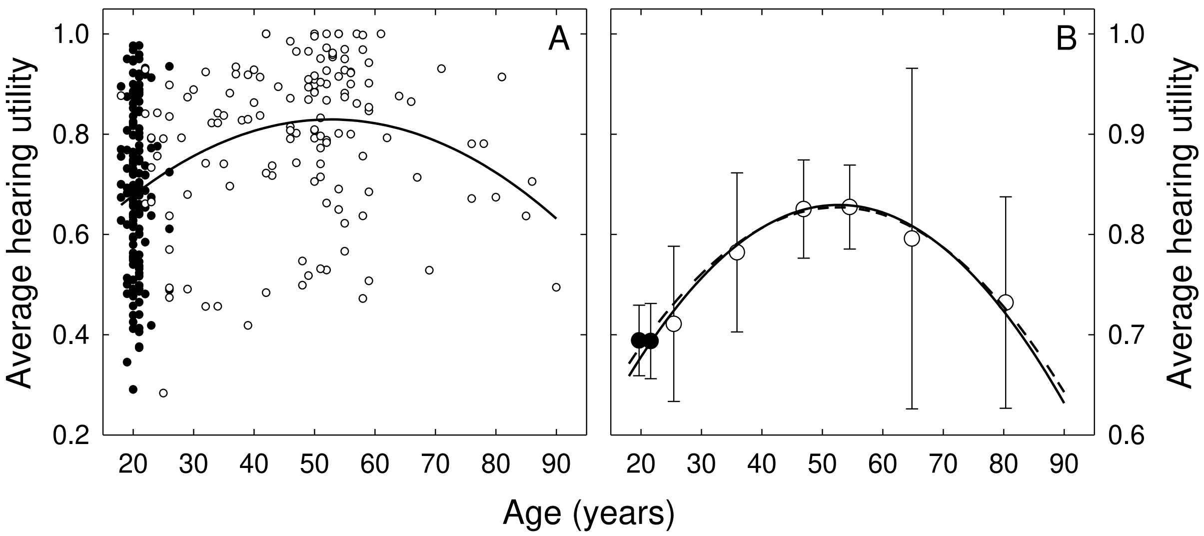

Figure 4 Analysis 4: In Panel A, overall utility is plotted against age for individual participants in Experiment 1a and for those participants in Experiment 1b who were instructed to imagine that their vision was perfect. Filled circles, students; open circles, non-students. Continuous line plots the quadratic function that best fits the data of non-students. In Panel B, overall utility is plotted with 95% confidence intervals for participants grouped by age in 10-year ranges plotted against the average age of the group. Filled circles, students; open circles, non-students. Continuous line is the quadratic function from Panel A. Dashed line is the quadratic function that best fits the data from non-students and students together.