Better visuospatial working memory in adults who report profound deafness compared to those with normal or poor hearing: data from the UK Biobank resource

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Profound deafness and visuospatial working memory

Introduction

Experimental work has shown better visuospatial working memory (VSWM) in profoundly deaf individuals compared to those with normal hearing. Other data, including the UK Biobank resource shows poorer VSWM in individuals with poorer hearing. Using the same database, we investigated VSWM in individuals who reported profound deafness.

Materials and Methods

Included in this study were 112 participants who were profoundly deaf, 1310 with poor hearing and 74 635 with normal hearing. All participants performed a card-pair matching task as a test of VSWM.

Results

Although variance in VSWM performance was large among profoundly deaf participants, at group level it was superior to that of participants with both normal and poor hearing.

Discussion

VSWM in adults is related to hearing status but the association is not linear. Future work should investigate the mechanism behind enhanced VSWM in profoundly deaf adults.

Key words: Deafness; hearing; visuospatial; working memory

Profoundly deaf individuals display differences in visual cognition compared to individuals with normal hearing (Bavelier et al., 2006). In particular, it has been shown that deaf adults (Geraci et al., 2008) and children (Wilson et al., 1997) perform better than peers with normal hearing on the Corsi blocks test, a measure of visuospatial working memory (VSWM). The Corsi blocks test requires the participant to retrace the pathway tapped out on a set of blocks by the test administrator. Thus, it requires memorization of a movement path through space. Differences in performance between deaf and hearing individuals on this task may be driven by differences in the visuospatial distribution of attention caused by deafness (Bavelier et al., 2006) and/or by experience of sign language, which requires representation of movement through space (Geraci et al., 1997; Wilson et al., 1997).

In a recent study based on data from the UK Biobank resource, we found poorer performance on a card pair matching task which taps into VSWM in individuals with poor hearing compared to individuals with normal hearing (Rönnberg et al., 2014). The UK Biobank resource includes data from 112 individuals who reported they were profoundly deaf and who performed the card pair matching task. In the present study, we predicted that this group would perform better than individuals with poor and normal hearing, demonstrating better VSWM for individuals with profound deafness according to data from a large observational study in line with previous experimental work.

Materials and methods

Participants

The UK Biobank resource includes data obtained from over 500,000 individuals aged 40-70 years who provided informed consent. For the present study and to ensure cultural homogeneity, we selected all individuals who were born in the UK or in the Republic of Ireland and who fell into one of three different categories (Normal Hearing, Poor Hearing, Profoundly Deaf) based on reported and measured hearing status. Hearing status was measured using the digit triplets test (Smits et al., 2004). There were 74,635 participants with normal hearing, i.e. they reported no hearing difficulty and had an unaided, best ear SRT < -5.5 dB (Dawes et al., 2014). There were 1310 participants with poor hearing, i.e. they did report hearing difficulty and had an SRT > -3.5 dB (Dawes et al., 2014)[1]. There were 112 participants who stated that they were completely deaf and who did not perform the SRT test.

Visuospatial working memory

Visuospatial working memory (VSWM) was measured using a computerized self-administered card-pair matching task with instructions and responses given on a touchscreen. In this task, six pairs of cards with matching symbols were displayed face up on the screen for five seconds for the participant to inspect. The pattern of matching symbols was random. The symbols on the cards were distinct, e.g. crescent moon, house; however no specific selection criteria were applied to choosing the designs. Such non-verbal stimuli could be recoded verbally into the participant's preferred language, which was likely to be English for the majority of participants but which may have been British Sign Language for some of the profoundly deaf participants.

Participants were instructed to memorize the position of as many matching pairs as possible during the brief period that the cards were shown. The cards were then turned face down on the screen and the participant was instructed to touch as many pairs as possible as accurately as possible. For the card-pair matching task, a demonstration video which could be watched repeatedly was provided to supplement written instructions. Deaf individuals, who have imperfect access to speech communication due to the absence of the auditory signal, are often poor readers (Marschark et al., 2012). Thus, importantly, the card-pair matching task not only made visuospatial demands in terms of temporary maintenance and processing, it could also be solved without reading instructions.

[1] Only about 30% of participants completed the hearing test which explains the relatively small size of the cohorts

making it a good instrument for testing our hypothesis that profound deafness enhances visuospatial cognition.

The dependent variable was the number of errors. As this variable was highly skewed, it was log-transformed.

Data analysis

Using case-wise deletion of missing data, a regression analysis was performed using VSWM as dependent variable, and hearing status and the demographic variables age, gender, education (at six levels: University or College degree or equivalent, Advanced levels or equivalent, Ordinary levels or General Certificate of Education or equivalent, Common Certificate of Education or equivalent, National Vocational Qualification or Higher National Diploma or Higher National Certificate or equivalent, or Other professional qualifications; e.g. nursing or teaching) and material deprivation based on the Townsend Deprivation Index (TDI, Townsend, Phillimore & Beattie, 1988). TDI is based on four census variables from the preceding national census output areas and was calculated immediately prior to the participant joining UK Biobank. Each participant was assigned a score corresponding to the output area in which their postcode was located. A greater TDI score implies a greater degree of material deprivation. The interaction effects of hearing status and demographic variables were also used as independent variables. Education and hearing status were entered as five and three dichotomous independent variables, respectively because linearity could not be established. The significance of all effects was determined with a multiple degree of freedom test. That is, a test of the overall effect of each variable (or interaction) was performed by testing the null hypothesis that the parameters involving that variable (or interaction) are all equal to zero. The non-standardised regression coefficients resulting from the analysis were used to estimate the effect of VSWM between hearing groups. Because the interaction effects were non-significant or relatively small, overall weighted effect sizes (E_w) were estimated by averaging the estimated effects for all combinations of discrete variables (gender, and education) when using mean values for the continuous variables (age and material deprivation). In this calculation, the effect for each combination of discrete variables was weighted with the sample size of that combination.

The study reported here is covered by a Research Tissue Bank approval obtained by UK Biobank from its governing Research Ethics Committee, as recommended by the National Research Ethics Service.

Results

Group VSWM performance is shown in Figure 1 and descriptive statistics in Table 1. The regression analysis showed a significant effect of hearing status on VSWM, see Table 2. The estimated weighted effect size of $E_w = 0.001$ transformed errors (SE of $E_w = 0.04$) was very small; providing some indication that performance was poorer for those with poor hearing status versus those with normal hearing. Because the deaf cohort is small, these effects are highly indicative of the effect between participants with normal and poor hearing. Looking at the difference between each group, the estimated effect sizes revealed that participants who were profoundly deaf, on average, performed better than participants with both normal (Effect = -0.150, SE of effect = 0.0903) and poor hearing (Effect = -.0186, SE of effect = 0.0942).

Insert Figure 1 and Tables 1 and 2 about here.

The pattern of results provides support for our prediction that performance among profoundly deaf individuals would exceed that of individuals with normal hearing. When we excluded the group with poor hearing from the regression analyses, the group of individuals who were profoundly deaf performed significantly better than the group with normal hearing, $p = 0.001$.

The covariates all contributed significantly to the prediction of VSWM, with age making the largest contribution: younger participants performed better than older participants. There was also a significant interaction between hearing status and education ($p = 0.004$). While better VSWM performance was associated with having a university or college degree in the groups with normal and poor hearing, it was associated with having a vocational qualification in the group of profoundly deaf participants. This may indicate that profoundly deaf individuals in the UK are not realizing their academic potential. However, given the small number of observations within each education level among the profoundly deaf (<15), this result should be interpreted with caution. No other interaction effects showed significant contributions, suggesting that the effects of all the covariates, including age were mostly similar across groups.

Discussion

The results of the present study show better VSWM in profoundly deaf individuals at group level compared to groups of individuals with either poor or normal hearing, when the demographic variables of age, gender, education and material deprivation are taken into account. These findings from a large observational study generalize previous experimental findings (Geraci et al., 2008). They may be driven by differences in visuospatial attention relating to hearing status (Bavelier et al., 2006) and/or by differences in visuospatial representation related to experience of sign language (Geraci et al., 1997; Wilson et al., 1997). The UK Biobank resource does not provide background data on these variables, and thus we are unable to separate their effects. However, they may well contribute to the large variation in performance.

Serial recall of spoken or written words is often poorer in deaf compared to hearing individuals (Andin et al., 2013). However, this disadvantage is not observed when stimuli are easily nameable pictures and temporal processing demands are relaxed (Rudner et al., 2010; Rudner & Rönnberg, 2008). Thus, it is likely that flexible encoding and storage as well as the provision of an instruction video supported the VSWM performance of profoundly deaf individuals in the present study. Future work should determine whether superior VSWM in profoundly deaf individuals is explained by differences in visuospatial attention caused by deafness or by enhanced visuospatial representation driven by sign language experience. Such knowledge may result in new interventions to counteract cognitive decline related to presbycusis.

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Table and Figure legends

Table 1. Descriptives for the three groups (Normal Hearing, Poor Hearing, Profoundly Deaf). Age is in years at time of recruitment. Sex is coded 0=female, 1=male. Education refers to highest level of qualification and is coded as follows 1=University or College degree or equivalents, 2=Advanced levels or equivalent, 3=Ordinary levels or General Certificate of Education or equivalent, 4=Common Certificate of Education or equivalent, 5=National Vocational Qualification or Higher National Diploma or Higher National Certificate or equivalent, 6=Other professional qualifications; e.g. nursing or teaching. TDI=Townsend Deprivation Index. A greater TDI score implies a greater degree of material deprivation. VSWM=Visuospatial Working Memory. These scores are log-transformed errors.

Table 2. The F-values, degrees of freedom (df), and significance levels for the effect of hearing status (including all three groups: normal hearing, poor hearing and profoundly deaf) and its interactions with gender, age, material deprivation (Townsend Deprivation Index) and education on visuospatial working memory. The denominator df was 65705.

Figure 1. Working memory performance. The graph shows the mean (filled circle), standard error (box), and 95% confidence interval (whiskers).