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Data in Brief

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Data Article

# Functional magnetic resonance imaging data of incremental increases in visuo-spatial difficulty in an adult lifespan sample



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### ABSTRACT

These data provide coordinates generated from a large healthy adult lifespan sample undergoing functional Magnetic Resonance Imaging (fMRI) while completing a spatial judgment task with varying levels of difficulty, as well as a control categorical condition. The data presented here include the average blood-oxygen-dependent (BOLD) response to the spatial judgment vs. the control task, as well as the BOLD response to incremental increasing difficulty; see also "Age-related Reduction of BOLD Modulation to Cognitive Difficulty Predicts Poorer Task Accuracy and Poorer Fluid Reasoning Ability" (Rieck et al., 2017) [1].

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## Specifications Table

| Subject area       | Cognitive Neuroscience                                    |
|--------------------|---|
| More specific sub- | Functional Magnetic Resonance Imaging of spatial judgment |
| ject area          |   |
| Type of data       | Coordinate tables, figures                                |

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| How data was<br>acquired               | Philips Achieva 3 T whole body scanner  |
|--|---|
| Data format<br>Experimental<br>factors | Analyzed using Statistical Parametric Mapping 8   |
| Experimental features                  | Participants performed a spatial judgment task in which they conducted two types of judgments. A categorical (LEFT/RIGHT) judgment was used as a control condition and a coordinate (NEAR/FAR) judgment was used with three levels of difficulty. |
| Data source<br>location                | Dallas, Texas, United States of America   |
| Data accessibility                     | Data provided in article  |

## Value of the data

- This dataset provides a sizable sample of healthy adults who performed a spatial judgment task.
- These data show differential BOLD responses for varying levels of visuo-spatial difficulty across the sample.
- The data provide specific MNI coordinates of brain regions evoked by the task.
- These data are potentially useful to investigators studying differences in fMRI activation to non-verbal, spatial stimuli across the adult lifespan.

## 1. Data

While undergoing fMRI, healthy adult participants completed a blocked-design spatial judgment task with three levels of difficulty (Easy, Medium, and Hard). These data have previously been analyzed with regard to age [1]. The data shown here represent the group level analyses examining the effect of the distance judgment task (Easy, Medium, Hard vs. Control – Table 1 and Fig. 1) as well as the effect of incremental increasing difficulty (Medium vs. Easy – Table 2 and Hard vs. Medium – Table 3, both shown in Fig. 2).

## 2. Experimental design, materials and methods

## 2.1. Participants

Participants included 161 healthy adults, ages 20-94 (mean age =  $51.93 \pm 18.9$  years; 95 women; 66 men) who volunteered from the Dallas-Fort Worth area. Inclusion criteria for the study required that all participants be right-handed, fluent English speakers, and have normal or corrected-to-normal vision (at least 20/40). Participants were also screened for dementia using the Mini Mental State Examination (MMSE; [2]), with a cutoff of 26; volunteers were also required to have no history of neurological or psychiatric conditions, head trauma, drug or alcohol problems, or significant cardiovascular disease (however, n=32 with a self-reported diagnosis of hypertension). Participants were compensated for their time and informed consent was obtained in accordance with protocol approved by the University of Texas at Dallas and the University of Texas Southwestern Medical Center.

#### 2.2. Experimental design

The data shared here are from a large lifespan dataset in which 161 healthy adults completed a blocked-design distance judgment task while undergoing fMRI. The spatial judgment task involved two types of judgments (modeled after [3] and [4]). The first type of judgment, which served as the

#### Table 1

Cluster peaks for the whole sample effect of distance judgment task [Easy, Medium, Hard vs. Control].

| Cluster Label         BA         k         X         Y         Z         t-value $p_{ree}$ L/R superior occipital gyrus         18         7013         -6         -102         6         17.3         <.001           and R precuncus         7         18         -66         45         14.46          .001           L/R middle fontal gyrus         8         745         6         21         42         12.82         <.001           gyrus         13         33         21         -3         11.6         <.001           insula         6         -45         6         27         10.64         .009           L inferior frontal gyrus         6         2.33         0         6         5.4         10.05         <.001           insula         9         -45         2.7         2.7         8.38         .004         .001         .001         .001  | A. Positive effect cluster-level |    |      |      |       |          |                 |              |
|--|----------------------------------|----|------|------|-------|----------|-----------------|--------------|
| $ \begin{array}{ccccc} L/R & \text{superior occipital gyrus} & 18 & 7013 & -6 & -102 & 6 & 17.3 & <.001 \\ and R precuneus & 7 & 27 & -72 & 36 & 13.94 \\ L/R & middle fontal gyrus & 8 & 745 & 6 & 21 & 42 & 12.82 & <.001 \\ & 6 & -24 & 0 & 51 & 9.62 \\ \hline R & middle and inferior frontal & 46 & 1409 & 45 & 36 & 18 & 12.54 & <.001 \\ gyrus & 13 & 33 & 21 & -3 & 11.55 \\ understand & 47 & 1305 & -30 & 21 & -3 & 11.6 & <.001 \\ insula & 6 & -45 & 6 & 27 & 10.64 \\ \hline R & middle frontal gyrus & 6 & 323 & 30 & 6 & 54 & 10.05 & <.001 \\ r & middle frontal gyrus & 6 & 323 & 30 & 6 & 54 & 10.05 & <.001 \\ R & thalamus/caudate & 50 & 88 & 18 & -27 & 15 & 6.5 & 0.004 \\ \hline R & thalamus/caudate & 48 & 18 & -15 & 18 & 6.1 \\ \ L & thalamus/caudate & 48 & 90 & -18 & -3 & 18 & 5.76 \\ L & thalamus/caudate & 48 & 90 & -18 & -3 & 18 & 6.1 \\ \hline R & middle frontal gyrus & 18 & 238 & -21 & -96 & -9 & 16.21 & <.001 \\ \hline R & 18 & 22 & 2342 & 60 & -45 & 12 & 148 & <.001 \\ \hline R & understand & 10 & 3230 & 0 & 57 & -9 & 16.21 & <.001 \\ R & understand & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial orbital and & 10 & 3230 & 0 & 57 & -9 & -15 & 10.48 \\ \ L/R & medial fontal gyrus & 21 & 278 & -57 & -9 & -15 & 10.48 \\ \ L & middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 1959 & -3 & -45 & 33 & 12.46 & <.001 \\ middle & model & 23 & 19$    | Cluster Label                    | BA | k    | X    | Y     | Z        | t-value         | <b>p</b> fwe |
| and R precuneus       7       18 $-66$ 45 $14.46$ $1/R$ middle frontal gyrus       8       745       6       21       42       12.82       <.001   | L/R superior occipital gyrus     | 18 | 7013 | -6   | - 102 | 6        | 17.3            | <.001        |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $  | and R precuneus                  | 7  |      | 18   | -66   | 45       | 14.46           |              |
| $ \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$  |                                  | 7  |      | 27   | -72   | 36       | 13.94           |              |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | L/R middle frontal gyrus         | 8  | 745  | 6    | 21    | 42       | 12.82           | <.001        |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $  |                                  | 6  |      | -24  | 0     | 51       | 9.62            |              |
| gyrus         13         33         21 $-3$ 11.55           L inferior frontal gyrus and<br>insula         6 $-45$ 6         24         10.99           R middle frontal gyrus         6         323         30         6         54         10.05         <.001   | R middle and inferior frontal    | 46 | 1409 | 45   | 36    | 18       | 12.54           | <.001        |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | gyrus                            | 13 |      | 33   | 21    | -3       | 11.55           |              |
| Linferior contal gyrus 18 332 21 -3 11.6 < .001<br>insula 6 -45 6 27 10.64<br>9 -45 27 27 8.38<br>R middle frontal gyrus 6 323 30 6 54 10.05 < .001<br>R thalamus/caudate 50 88 18 -27 15 6.5 0.004<br>48 18 -15 18 6.1<br>48 18 -15 18 6.1<br>48 -18 0 18 6.1<br>50 -15 -6 6 4.59<br>B. Negative effect cluster-level $V$<br>R lingual gyrus 18 332 21 -90 -3 17.86 < .001<br>L inferior occipital gyrus 18 238 -21 -96 -9 16.21 < .001<br>R superior and middle 22 2342 60 -45 12 14.8 < .001<br>temporal gyrus 39 60 -60 21 12.59<br>L/R medial orbital and 10 3230 0 57 -3 12.61 < .001<br>middle frontal gyrus; 8 -21 33 42 11.57<br>L/R medial orbital and 10 3230 0 57 -3 12.61 < .001<br>middle frontal gyrus 23 -66 -27 10.44<br>L/R posterior and middle 23 1959 -3 -45 33 12.46 < .001<br>middle frontal gyrus 23 -66 -27 10.44<br>L/R posterior and middle 23 1959 -3 -45 33 12.46 < .001<br>middle frontal gyrus 23 -66 -27 39 10.5<br>L middle frontal gyrus 8 -21 33 42 11.57<br>19 -57 -69 -15 10.48<br>L/R posterior and middle 23 1959 -3 -45 33 12.46 < .001<br>middle frontal gyrus 24 3 -21 39 10.6<br>L middle frontal gyrus 24 3 -21 39 10.5<br>L middle frontal gyrus 24 3 -21 39 10.6<br>L middle frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 37 -54 -9 -15 8.55 < .001<br>L orbital frontal gyrus 37 -54 -9 -15 8.55 < .001<br>L orbital frontal gyrus 37 -30 -33 -35 5.54<br>L inferior temporal gyrus 20 41 -45 3 -3 -36 5.74 0.031<br>R cerebellum crus 2 46 21 -87 -39 5.06 0.031<br>R cerebellum crus 2 46 21 -87 -39 5.06 0.031<br>B -30 -81 -36 5.4 4.85                              |                                  | 44 |      | 48   | 6     | 24       | 10.99           |              |
| insula         6 $-45$ 6         27         10.64           9 $-45$ 27         27         8.38           R middle frontal gyrus         6         323         30         6         54         10.05 $<.001$ R thalamus/caudate         50         88         18 $-27$ 15         6.5         0.004           48         18 $-15$ 18         6.1         5.7         0.004           48         18 $-27$ 15         6.27         0.004           48 $-18$ 0         18         6.1         5.7         0.004           48 $-18$ 0         18         6.1         5.7         0.004           48 $-18$ $-27$ 15         6.27         0.004           10         50 $-15$ $-6$ 4.59         4.59           R ingual gyrus         18         332         21 $-90$ $-3$ 17.86 $<.001$ Linferior occipital gyrus         18         232 $-21$ $-96$ $-15$ 10.48   | L inferior frontal gyrus and     | 47 | 1305 | -30  | 21    | -3       | 11.6            | <.001        |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | insula                           | 6  |      | -45  | 6     | 27       | 10.64           |              |
| $ \begin{array}{c c c c c c c c c c c c c c c c c c c $  |                                  | 9  |      | -45  | 27    | 27       | 8.38            |              |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | R middle frontal gyrus           | 6  | 323  | 30   | 6     | 54       | 10.05           | <.001        |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | R thalamus/caudate               | 50 | 88   | 18   | -27   | 15       | 6.5             | 0.004        |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   |                                  | 48 |      | 18   | - 15  | 18       | 6.1             |              |
| L thalamus/caudate 48 90 -18 -27 15 6.27 0.004<br>48 -18 0 18 6.1<br>50 -15 -6 6 4.59<br>B. Negative effect cluster-level<br>Cluster Label BA k X Y Z t-value $p_{fwe}$<br>R lingual gyrus 18 332 21 -90 -3 17.86 < .001<br>L inferior occipital gyrus 18 238 -21 -96 -9 16.21 < .001<br>R superior and middle 22 2342 60 -45 12 14.8 < .001<br>temporal gyrus 29 60 -60 21 12.59<br>21 57 -9 -15 10.48<br>L/R medial orbital and 10 3230 0 57 -3 12.61 < .001<br>middle frontal gyrus; 8 -21 33 42 11.57<br>anterior cingulate 10 9 54 12 11.16<br>L/R posterior and middle 23 1959 -3 -45 33 12.46 < .001<br>cingulate gyrus 24 3 -21 39 10.6<br>L middle cocipital and 39 1429 -45 -75 39 11.8 < .001<br>posterior parietal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 54 112 27 -12 -18 6.61 0.001<br>L orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 33 -15 7.75 0.003<br>R orbital frontal gyrus 47 95 -33 -36 5.1 0.0022<br>38 -33 -39 4.51 |                                  | 48 |      | 18   | -3    | 18       | 5.76            |              |
| 48 $-18$ 0       18       6.1         50 $-15$ $-6$ 6       4.59         B. Negative effect cluster-level       BA       k       X       Y       Z       t-value $p_{fwe}$ R lingual gyrus       18       332       21 $-90$ $-3$ 17.86 $< .001$ L inferior occipital gyrus       18       238 $-21$ $-96$ $-9$ 16.21 $< .001$ R superior and middle       22       2342 $60$ $-45$ 12       14.8 $< .001$ temporal gyrus       21 $57$ $-9$ $-15$ 10.48 $< .001$ L/R medial orbital and       10       3230       0 $57$ $-3$ 12.61 $< .001$ middle fontal gyrus;       8 $-21$ 33       42       11.57         anterior cingulate       10       9 $54$ 12       11.16         L/R posterior and middle       23 $195$ $-37$ $-32$ $2.06$ $-27$ $39$ 10.6         action cingulate gyrus       24 $3$ $-21$  | L thalamus/caudate               | 48 | 90   | - 18 | -27   | 15       | 6.27            | 0.004        |
| 50 $-15$ $-6$ $6$ $4.59$ B. Negative effect cluster-level         Cluster Label         BA $k$ $X$ $Y$ $Z$ $t-value$ $p$ fore           R lingual gyrus         18         332         21 $-90$ $-3$ 17.86 $<.001$ L inferior occipital gyrus         18         238 $-21$ $-96$ $-9$ 16.21 $<.001$ R superior and middle         22         2342 $60$ $-45$ 12         14.8 $<.001$ L/R medial orbital and         10         3230 $0$ $57$ $-3$ 12.61 $<.001$ Middle frontal gyrus;         8 $-21$ 33 $42$ $11.57$ anterior cingulate         10         9 $54$ 12 $11.61$ $<.001$ L/R posterior and middle         23         1959 $-3$ $-45$ 33 $12.46$ $<.001$ Lindle occipital and         10         9 $54$ 12 $11.8$ $<.001$ posterior parietal gyrus </td <td></td> <td>48</td> <td></td> <td>- 18</td> <td>0</td> <td>18</td> <td>6.1</td> <td></td>  |                                  | 48 |      | - 18 | 0     | 18       | 6.1             |              |
| B. Negative effect cluster-level         BA         k         X         Y         Z         r-value $p_{fwc}$ R lingual gyrus         18         332         21 $-90$ $-3$ 17.86 $< .001$ L inferior occipital gyrus         18         238 $-21$ $-96$ $-9$ $16.21$ $< .001$ R superior and middle         22         2342 $60$ $-45$ 12 $14.8$ $< .001$ L/R medial orbital and         0         3230 $0$ $-77$ $-9$ $-15$ $10.48$ L/R medial orbital and         0         3230 $0$ $57$ $-3$ $12.61$ $< .001$ middle frontal gyrus;         8 $-21$ $33$ $42$ $11.57$ anterior cingulate         10         9 $54$ 12 $11.16$ L/R posterior and middle         23         1959 $-3$ $-21$ $39$ $10.5$ L middle occipital and         39 $1429$ $-45$ $-75$ $39$ $11.8$ $< .001$ <t< td=""><td></td><td>50</td><td></td><td>- 15</td><td>-6</td><td>6</td><td>4.59</td><td></td></t<>   |                                  | 50 |      | - 15 | -6    | 6        | 4.59            |              |
| Cluster Label         BA         k         X         Y         Z         t-value $p_{twe}$ R lingual gyrus         18         332         21         -90         -3         17.86         <.001  | B. Negative effect cluster-level |    |      |      |       |          |                 |              |
| R lingual gyrus       18       332       21 $-90$ $-3$ $17.86$ $<.001$ L inferior occipital gyrus       18       238 $-21$ $-96$ $-9$ $16.21$ $<.001$ R superior and middle       22 $2342$ $60$ $-45$ $12$ $14.8$ $<.001$ temporal gyrus $39$ $60$ $-60$ $21$ $12.59$ $21$ $57$ $-9$ $-15$ $10.48$ $L/R$ medial orbital and       10 $3230$ $0$ $57$ $-3$ $12.61$ $<.001$ middle frontal gyrus; $8$ $-21$ $33$ $42$ $11.57$ anterior cingulate $10$ $9$ $54$ $12$ $11.66$ L/R posterior and middle $23$ $1959$ $-3$ $-45$ $33$ $12.46$ $<.001$ cingulate gyrus $24$ $3$ $-21$ $39$ $10.6$ $23$ $-6$ $-27$ $39$ $10.6$ L       middle occipital and $39$ $1429$ $-45$ $-75$ $39$   | Cluster Label                    | BA | k    | X    | Y     | Z        | <i>t</i> -value | p fwe        |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | R lingual gyrus                  | 18 | 332  | 21   | _ 9(  | ) _      | 3 1786          | < 001        |
| Initial order and middle<br>temporal gyrus12234260 $-45$ 1214.8 $<.001$ $k$ superior and middle<br>temporal gyrus3960 $-60$ 2112.59 $21$ $57$ $-9$ $-15$ 10.48 $L/R$ medial orbital and<br>middle frontal gyrus;8 $-21$ 3342 $k$ medial orbital and<br>middle frontal gyrus;8 $-21$ 3342 $k$ middle frontal gyrus;8 $-21$ 334211.67 $k$ middle frontal gyrus;8 $-21$ 3312.46 $<.001$ $k$ middle gyrus243 $-21$ 3910.6 $k$ middle occipital and<br>posterior parietal gyrus24 $3$ $-21$ 3910.6 $k$ middle temporal gyrus21 $278$ $-66$ $-27$ 3911.8 $<.001$ $k$ middle temporal gyrus21 $278$ $-54$ $-9$ $-15$ $8.55$ $<.001$ $k$ middle temporal gyrus21 $278$ $-54$ $-9$ $-15$ $8.55$ $<.001$ $k$ middle frontal gyrus47933636 $-12$ $7.06$ $0.003$ $k$ orbital frontal gyrus4793 $36$ $36$ $-12$ $7.06$ $0.003$ $k$ hippocampus $54$ $12$ $277$ $-12$ $-18$ $6.61$ $0.001$ $k$ cerebellum crus 2 $39$ $-24$ $-81$ $-36$ $5.74$ $0.031$ $k$ hippocampus and fusiform $54$ $65$ $-27$ $-1$   | L inferior occipital gyrus       | 18 | 238  | -21  | - 96  | ,<br>i – | 9 16.21         | < 001        |
| Interported under<br>temporal gyrus2910101210101010102157 $-9$ $-15$ $10.48$ L/R medial orbital and<br>middle frontal gyrus;8 $-21$ 3342 $11.57$ anterior cingulate1095412 $11.16$ L/R posterior and middle23 $1959$ $-3$ $-45$ 33 $12.46$ $<.001$ cingulate gyrus243 $-21$ 39 $10.6$ $<.011$ cingulate gyrus243 $-21$ 39 $10.6$ 23 $-6$ $-27$ 39 $10.5$ $<.011$ posterior parietal gyrus29 $-45$ $-75$ $39$ $11.8$ $<.001$ posterior parietal gyrus21 $278$ $-54$ $-9$ $-15$ $8.55$ $<.001$ L middle temporal gyrus21 $278$ $-54$ $-9$ $-15$ $8.55$ $<.001$ L orbital frontal gyrus4795 $-33$ $33$ $-15$ $7.75$ $0.003$ R orbital frontal gyrus4793 $36$ $36$ $-12$ $706$ $0.003$ L cerebellum crus 239 $-24$ $-81$ $-36$ $5.74$ $0.001$ L cerebellum crus 239 $-24$ $-81$ $-36$ $5.44$ L inferior temporal gyrus20 $41$ $-45$ $3$ $-36$ $5.1$ $0.022$ $38$ $-33$ $3$ $-39$ $4.51$ $-36$ $4.48$   | R superior and middle            | 22 | 2342 | 60   | -44   | 5 13     | 2 14.8          | < 001        |
| Line of the point gives2157 $-9$ $-15$ $10.48$ L/R medial orbital and<br>middle frontal gyrus;<br>anterior cingulate10 $9$ $54$ $12$ $11.57$ anterior cingulate10 $9$ $54$ $12$ $11.16$ L/R posterior and middle23 $1959$ $-3$ $-45$ $33$ $12.46$ $<.001$ cingulate gyrus $24$ $3$ $-21$ $39$ $10.6$ $L/R model cocipital andposterior parietal gyrus39-66-2773911.8<.001posterior parietal gyrus39-57-632710.4419-57-69910.4L middle temporal gyrus21278-54-9-158.55<.001L orbital frontal gyrus4795-3333-157.750.003R orbital frontal gyrus47933636-127.060.003L cerebellum crus 239-24-81-365.740.031L hippocampus and fusiform5465-27-15-185.610.00238-333-394.51-30-33-365.44L inferior temporal gyrus2041-453-365.140.02238-333-394.51-364.48$   | temporal gyrus                   | 39 | 2012 | 60   | -60   | ) 2      | 1 12.59         |              |
| L/R medial orbital and<br>middle frontal gyrus;<br>anterior cingulate103230057 $-3$ 12.61<.001middle frontal gyrus;<br>anterior cingulate109541211.16L/R posterior and middle231959 $-3$ $-45$ 3312.46<.001  | temporar gyrab                   | 21 |      | 57   | -9    | -        | 15 10.48        |              |
| middle frontal gyrus;<br>anterior cingulate8-21334211.57anterior cingulate109541211.6L/R posterior and middle231959-3-453312.46<.001   | L/R medial orbital and           | 10 | 3230 | 0    | 57    | _        | 3 12.61         | < .001       |
| anterior cingulate       10       9       54       12       11.16         L/R posterior and middle       23       1959       -3       -45       33       12.46       <.001   | middle frontal gyrus:            | 8  |      | -21  | 33    | 4        | 2 11.57         |              |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   | anterior cingulate               | 10 |      | 9    | 54    | 12       | 2 11.16         |              |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | L/R posterior and middle         | 23 | 1959 | -3   | -45   | 5 3      | 3 12.46         | <.001        |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$  | cingulate gyrus                  | 24 |      | 3    | -21   | 3        | 9 10.6          |              |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | 0 00                             | 23 |      | -6   | -27   | 7 3      | 9 10.5          |              |
| $\begin{array}{c c c c c c c c c c c c c c c c c c c $   | L middle occipital and           | 39 | 1429 | -45  | -75   | 5 3      | 9 11.8          | <.001        |
| 111-57-69910.4Lmiddle temporal gyrus21278 $-54$ $-9$ $-15$ $8.55$ $<.001$ Lorbital frontal gyrus4795 $-33$ $33$ $-15$ $7.75$ $0.003$ Rorbital frontal gyrus4793 $36$ $36$ $-12$ $7.06$ $0.003$ R $45$ $54$ $33$ 0 $5.93$ $-12$ $7.06$ $0.001$ Lcerebellum crus 2 $39$ $-24$ $-81$ $-36$ $5.74$ $0.031$ Lhippocampus and fusiform $54$ $65$ $-27$ $-15$ $-18$ $5.61$ $0.008$ gyrus $37$ $-30$ $-33$ $-15$ $5.44$ $-36$ $5.14$ $0.022$ 38 $-33$ $3$ $-39$ $4.51$ $-36$ $4.48$ R cerebellum crus 2  | posterior parietal gyrus         | 39 |      | -57  | -63   | 3 2      | 7 10.44         |              |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   |                                  | 19 | _    | 57   | -69   | 9 9      | 10.4            |              |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   | L middle temporal gyrus          | 21 | 278  | -54  | -9    | _        | 15 8.55         | <.001        |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   | L orbital frontal gyrus          | 47 | 95   | -33  | 33    | _        | 15 7.75         | 0.003        |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   | R orbital frontal gyrus          | 47 | 93   | 36   | 36    | _        | 12 7.06         | 0.003        |
| $ \begin{array}{c ccccccccccccccccccccccccccccccccccc$   | 05                               | 45 |      | 54   | 33    | 0        | 5.93            |              |
| $ \begin{array}{cccccccccccccccccccccccccccccccccccc$  | R hippocampus                    | 54 | 112  | 27   | - 12  | 2 –      | 18 6.61         | 0.001        |
| L hippocampus and fusiform 54 65 -27 -15 -18 5.61 0.008<br>gyrus 37 -30 -33 -15 5.44<br>L inferior temporal gyrus 20 41 -45 3 -36 5.1 0.022<br>38 -33 3 -39 4.51<br>R cerebellum crus 2 46 21 -87 -39 5.06 0.031<br>30 -81 -36 4.48  | L cerebellum crus 2              |    | 39   | -24  | -8    | I –      | 36 5.74         | 0.031        |
| gyrus         37         -30         -33         -15         5.44           L inferior temporal gyrus         20         41         -45         3         -36         5.1         0.022           38         -33         3         -39         4.51           R cerebellum crus 2         46         21         -87         -39         5.06         0.031           30         -81         -36         4.48         30         -81         -36         4.48   | L hippocampus and fusiform       | 54 | 65   | -27  | - 15  | ; –      | 18 5.61         | 0.008        |
| L inferior temporal gyrus 20 41 -45 3 -36 5.1 0.022<br>38 -33 3 -39 4.51<br>R cerebellum crus 2 46 21 -87 -39 5.06 0.031<br>30 -81 -36 4.48  | gyrus                            | 37 |      | -30  | -33   | 3 –      | 15 5.44         |              |
| 38         -33         3         -39         4.51           R cerebellum crus 2         46         21         -87         -39         5.06         0.031           30         -81         -36         4.48         30         -81         -36         4.48   | L inferior temporal gyrus        | 20 | 41   | -45  | 3     | -        | 36 5.1          | 0.022        |
| R cerebellum crus 2 46 21 -87 -39 5.06 0.031<br>30 -81 -36 4.48  | 1 05                             | 38 |      | -33  | 3     | -        | 39 4.51         |              |
| 30 -81 -36 4.48  | R cerebellum crus 2              |    | 46   | 21   | -87   | 7 _      | 39 5.06         | 0.031        |
|  |                                  |    |      | 30   | -8    | l –      | 36 4.48         |              |

*Note.* p < .0001 uncorrected, cluster-level FWE p < .05 correction. BA=Brodmann's area.

control condition, required participants to make a categorical (LEFT/RIGHT) judgment. Participants saw a dot on the left or right side of a horizontal bar and had to indicate using a button press on which side of the bar the dot was present.



**Fig. 1.** *Effect of Easy, Medium, and Hard Tasks vs. Control.* Hot blobs indicate regions in which there was greater activity during all levels (Easy, Medium, Hard) of the coordinate distance judgment task versus the coordinate control task. Cool blobs indicate regions in which there was greater activity during the left-right coordinate control condition. Color scale indicates *t*-values; *Abbreviations:* LH – Left Hemisphere; RH – Right Hemisphere.

Participants also made a coordinate (NEAR/FAR) distance judgment which had three levels of difficulty: Easy, Medium, and Hard. First, participants saw a vertical reference line, next they were shown a horizontal line with a dot either above or below the line; the judgment required participants to determine whether the dot was "nearer to" or "farther from" the horizontal bar, given the previously seen vertical line. As difficulty increased, the distance between the dot and the horizontal line became harder to determine the "nearness" or "farness" compared to the reference line. A schematic of the task can be found in Fig. 1 of Rieck and colleagues [1]. Prior to the scanning session, participants completed a practice session to ensure that the participants were comfortable with the instructions. Each participant completed three runs of the task, resulting in  $\sim$ 15 min of scan time. The task was presented using PsychoPy v1.77.02 [5,6].

## 2.3. Image acquisition

Data were acquired on a single Philips Achieva 3 T whole body scanner using a 32-channel head coil. BOLD fMRI data were collected using a T2\*-weighted echo planar imaging sequence in 29 interleaved axial slices parallel to AC-PC line,  $64 \times 64 \times 29$  matrix,  $3.4 \times 3.4 \times 5$  mm<sup>3</sup>, Field of View (FOV)=220 mm, Echo Time (TE)=30 ms, Repetition Time (TR)=1500 ms. High-resolution anatomical images were also acquired with a T1-weighted MP-RAGE sequence with the following parameters: 160 sagittal slices,  $1 \times 1 \times 1$  mm<sup>3</sup> voxels;  $256 \times 204 \times 160$  matrix, FOV=256 mm, TE=3.8 ms, TR=8.3 ms, Flip angle=12°.

## 2.4. Image processing

Data from each individual were preprocessed using SPM8 (Wellcome Department of Cognitive Neurology, London, UK). Preprocessing included the following steps: slice time acquisition correction, motion correction, normalization, and smoothing (using an isotropic 8 mm<sup>3</sup> full-width-half-maximum Gaussian kernel). In order to identify runs with motion outliers, ArtRepair [7] was used to determine potential outlier volumes for each participant. We examined all three runs for each participant, and runs that had more than 15% outlier volumes ( $\sim$ 30 volumes) with greater than 3% deviation from the mean in global intensity spikes or greater than 2 mm of motion displacement

| Table | 2 |
|-------|---|
|-------|---|

| Cluster | peaks fo | r the | whole | sample | effect | of i | ncreasing | difficulty | / from | Easy i | to Mediur | n. |
|---------|----------|-------|-------|--------|--------|------|-----------|------------|--------|--------|-----------|----|
|         |          |       |       |        |        |      |           |            |        |        |           |    |

| A. Increased activation from easy to medium cluster-level |          |             |      |       |      |         |              |  |  |  |
|---|----------|-------------|------|-------|------|---------|--------------|--|--|--|
| Cluster Label   | BA       | k           | X    | Y     | Ζ    | t-value | <b>p</b> fwe |  |  |  |
| L superior and middle                                     | 18       | 344         | -9   | - 102 | 9    | 9.58    | <.001        |  |  |  |
| occipital gyrus   | 18       |             | -24  | -93   | 15   | 7.68    |              |  |  |  |
|   | 18       |             | -36  | - 78  | 3    | 4.66    |              |  |  |  |
| R cuneus and middle occipital                             | 18       | 536         | 12   | -96   | 15   | 9.51    | < .001       |  |  |  |
| gyrus   | 18       |             | 27   | -87   | 18   | 8.18    |              |  |  |  |
|   | 18       |             | 3    | -81   | -3   | 6.21    |              |  |  |  |
| L/R anterior cingulate gyrus                              | 8        | 71          | 6    | 21    | 42   | 5.48    | 0.008        |  |  |  |
|   | 32       |             | -6   | 21    | 39   | 4.26    |              |  |  |  |
| B. Deceased activation from easy to n                     | nedium c | luster-leve |      |       |      |         |              |  |  |  |
| Cluster Label   | BA       | k           | X    | Y     | Ζ    | t-value | p fwe        |  |  |  |
|   |          |             |      |       |      |         |              |  |  |  |
| R inferior occipital gyrus                                | 18       | 200         | 24   | -93   | -3   | 9.99    | <.001        |  |  |  |
| L inferior occipital gyrus and                            | 18       | 379         | - 18 | -93   | -9   | 8.68    | <.001        |  |  |  |
| cerebellum crus 1 & 2                                     |          |             | -21  | -78   | - 39 | 6.22    |              |  |  |  |
|   |          |             | -33  | -84   | -30  | 6.15    |              |  |  |  |
| R middle temporal and gyrus                               | 39       | 747         | 54   | -60   | 21   | 7.63    | <.001        |  |  |  |
| angular gyrus   | 37       |             | 66   | -48   | -3   | 5.59    |              |  |  |  |
|   | 39       |             | 48   | -66   | 39   | 4.93    |              |  |  |  |
| L/R posterior cingulate gyrus                             | 23       | 814         | 6    | -45   | 30   | 6.32    | < .001       |  |  |  |
| and precuneus   | 7        |             | 0    | - 57  | 45   | 6.31    |              |  |  |  |
|   | 7        |             | -6   | - 57  | 66   | 6.25    |              |  |  |  |
| L middle and superior                                     | 8        | 215         | -30  | 27    | 48   | 6.12    | <.001        |  |  |  |
| frontal gyrus   | 8        |             | - 15 | 39    | 45   | 4.49    |              |  |  |  |
|   | 9        |             | -36  | 36    | 36   | 4.11    |              |  |  |  |
| R cerebellum crus 1                                       |          | 358         | 54   | -66   | -33  | 6.02    | <.001        |  |  |  |
|   |          |             | 45   | -72   | -33  | 5.14    |              |  |  |  |
|   |          |             | 27   | -81   | -30  | 5.08    |              |  |  |  |
| L posterior parietal and                                  | 39       | 573         | -39  | -72   | 42   | 5.82    | <.001        |  |  |  |
| middle temporal gyrus                                     | 39       |             | -54  | -45   | 30   | 5.57    |              |  |  |  |
|   | 39       |             | -51  | -63   | 18   | 5.13    |              |  |  |  |
| R middle frontal gyrus                                    | 8        | 74          | 27   | 30    | 45   | 5.35    | 0.007        |  |  |  |
| R middle temporal gyrus                                   | 21       | 94          | 60   | -9    | - 18 | 5.33    | 0.003        |  |  |  |
| L interior temporal gyrus                                 | 37       | 99          | -57  | -51   | -6   | 5.2     | 0.003        |  |  |  |
| L/K superior medial frontal                               | 10       | 3/          | 12   | 63    | 15   | 4.99    | 0.039        |  |  |  |

*Note.* p < .0001 uncorrected, cluster-level FWE p < .05. BA=Brodmann's area.

were flagged. Five participants had one run with more than 15% percent outlier volumes, so that run was excluded.

At the individual subject level, BOLD response to each condition (Control, Easy, Medium, Hard) was modeled in SPM as a block convolved with a canonical hemodynamic response function; six directions of motion-estimates for each volume generated from ArtRepair were also included as nuisance covariates. Several contrasts of interest were computed at the individual level for subsequent analysis at the group level: Easy+Medium+Hard vs. Control (Table 1, Fig. 1), which represents the effect of the distance judgment task; and Medium vs. Easy (Table 2, Fig. 2), Hard vs. Medium (Table 3, Fig. 2) to examine the brain regions responsive to increment increases in difficulty for visuo-spatial judgments.

#### Table 3

| Cluster | peaks t | for the | whole | sample | effect | ofi | increasing | difficulty | from | Medium | to H | lard |
|---------|---------|---------|-------|--------|--------|-----|------------|------------|------|--------|------|------|
|         |         |         |       |        |        |     |            |            |      |        |      |      |

| A. Increased activation from medi | ium to har | d cluster-lev                         | el   |     |      |         |              |
|-----------------------------------|------------|---------------------------------------|------|-----|------|---------|--------------|
| Cluster Label                     | BA         | k                                     | X    | Y   | Ζ    | t-value | <b>p</b> fwe |
| R inferior and superior           | 7          | 1315                                  | 42   | -51 | 54   | 8.6     | <.001        |
| parietal lobule                   | 7          |                                       | 33   | -60 | 54   | 8.43    |              |
|                                   | 40         |                                       | 42   | -42 | 42   | 8.3     |              |
| R inferior frontal and            | 9          | 2220                                  | 48   | 33  | 21   | 8.38    | <.001        |
| insula                            | 44         |                                       | 48   | 9   | 24   | 8.32    |              |
|                                   | 13         |                                       | 30   | 24  | -3   | 7.88    |              |
| L cerebellum crus 1 & 2           |            | 476                                   | -9   | -81 | - 33 | 8.29    | <.001        |
|                                   |            |                                       | -33  | -72 | -48  | 7.77    |              |
|                                   |            |                                       | - 30 | -66 | - 30 | 7.2     |              |
| R superior medial frontal gyrus   | 8          | 432                                   | 9    | 27  | 45   | 7.21    | <.001        |
|                                   | 8          |                                       | 3    | 33  | 39   | 6.98    |              |
| R lingual gyrus                   | 18         | 37                                    | 18   | -87 | -6   | 6.75    | 0.04         |
| L insular cortex                  | 13         | 99                                    | -33  | 21  | -3   | 6.42    | 0.003        |
| L inferior frontal gyrus          | 44         | 53                                    | - 57 | 21  | 30   | 5.45    | 0.019        |
| L middle occipital gyrus          | 18         | 35                                    | -36  | -93 | 9    | 5.09    | 0.044        |
| L orbitofrontal gyrus             | 47         | 41                                    | -45  | 45  | -6   | 5.06    | 0.033        |
| L inferior and superior           | 40         | 141                                   | -39  | -48 | 48   | 4.81    | 0.001        |
| parietal lobule                   | 39         |                                       | -33  | -57 | 48   | 4.79    |              |
|                                   | 7          |                                       | -21  | -66 | 51   | 4.6     |              |
| B. Deceased activation from medi  | um to hard | l cluster-leve                        | 1    |     |      |         |              |
| Cluster Label                     | BA         | k                                     | X    | Y   | Ζ    | t-value | <b>p</b> fwe |
|                                   |            | i i i i i i i i i i i i i i i i i i i |      |     |      |         |              |
| L/R posterior and anterior        | 18         | 10811                                 | 0    | -72 | 24   | 10.96   | <.001        |
| medial wall and                   | 10         |                                       | -3   | 57  | -3   | 9.75    |              |
| precuneus                         |            |                                       |      |     |      |         |              |
|                                   | 23         |                                       | 9    | -57 | 27   | 9.29    |              |
| L middle temporal and             | 39         | 1846                                  | -42  | -57 | 21   | 8       | <.001        |
| angular gyrus                     | 39         |                                       | -42  | -72 | 36   | 7.19    |              |
|                                   | 21         |                                       | -54  | -6  | - 18 | 6.93    |              |
| L superior frontal gyrus          | 8          | 222                                   | - 18 | 33  | 42   | 7.06    | <.001        |
| L orbital frontal gyrus           | 47         | 69                                    | -27  | 36  | - 15 | 6.31    | .014         |

*Note.* p < .0001 uncorrected, cluster-level FWE p < .05. BA=Brodmann's area.



**Fig. 2.** Effect of incremental increasing difficulty across the entire sample. Panel A shows the contrast of activation for Medium m > Easy trials. Panel B shows the contrast of activation to Hard > Medium trials. Color scale indicates *t*-values. *Abbreviations*: LH – Left Hemisphere; RH – Right Hemisphere.

## **Conflict of Interest**

The authors (KMK, JRR, MAB, KMR) of this manuscript (Functional magnetic resonance imaging data of incremental increases in visuo-spatial difficulty in an adult lifespan sample) have no conflicts of interest to report.

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