

# **Influence of handedness and bilateralism on cerebralization**

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## ABSTRACT

We investigated the effects of incidence of hemispheric specialization (HHS) on cerebralization dimensions (asymmetry, lateralization, and originality) of healthy elderly subjects. To measure handedness, we used the Edinburgh Handedness Inventory (EHI). The EHI also indicates bilateralism. Individual differences in handedness, mixed-handedness, and bilateralism were assessed using a 30-item emotional rating scale (EM). Results indicate significant correlations between handedness, cognitive function, and emotional rating scale scores.

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Fo e am le, Ch i man (2001) ob e ed ha lef -hande<sub>s</sub>, a mo e mi ed-handed g o han igh hande<sub>s</sub> (B den & S eenh i , 1991; Ch i man, 1995; Hellige, 1993), e hibi ed g ea -e S oo in e fe ence and g ea e local global in e fe ence, hich  $\frac{g}{2}$  in e e ed  $\frac{g}{2}$  lec ing g ea e in e ac ion be een LH-ba ed e bal/local oce<sub>s</sub> ing and RH-ba ed ch oma ic/global oce<sub>s</sub> ing. F he , P o e , Ch i man, and Phane f (2005) ob e ed an ad an age fo mi ed-hande<sub>s</sub> o e ong-hande<sub>s</sub> on e i odic e ie al  $\frac{g}{2}$ , con e ging on h<sub>s</sub> iological  $\frac{g}{2}$  ea ch im lica ing bila e al a e  $\frac{g}{2}$  of ac i i fo enhanced e fo mance on e i odic memo  $\frac{g}{2}$  (Pla el, Ba on, De g ang $\frac{g}{2}$ , Be na d, & E<sub>s</sub> a che, 2003; T l ing, Ka , C aik, M<sub>s</sub> co i ch, & Ho le, 1994). Mi ed-hande<sub>s</sub> al o ha e an ad an age o e ong-hande<sub>s</sub> fo o he memo  $\frac{g}{2}$  ha o ld bene f om inc e $\frac{g}{2}$  ed IHI (e.g., o ce memo ), b $\frac{g}{2}$  ho no ch ad an age on memo  $\frac{g}{2}$  ha o ld no e i e IHI (e.g., face ecogni ion) (L le, McCabe, & Roedige , 2008). While c ea i i and deg ee of handedne<sub>s</sub> ha no been di ec l $\frac{g}{2}$  died (al ho gh he e a e $\frac{g}{2}$  ome $\frac{g}{2}$  die $\frac{g}{2}$  ha ha e e amined di ec ion of handedne<sub>s</sub> and c ea i i ), mi ed-handedne<sub>s</sub> ha been  $\frac{g}{2}$  ocia ed i h g ea e magical idea ion (Ba ne & Co balli , 2002), and a i $\frac{g}{2}$  ha e a highe incidence of ini ali and mi ed-handedne<sub>s</sub> (P e i & Vellane, 2007). F -he , mi ed-hande<sub>s</sub> gene a e mo e al e na e-ending o cena iq (i.e., co n e fac al ho gh ) han do ong-hande<sub>s</sub> (Ja e , Ba , & Ch i man, 2008), and he f on al co e of bo h hemi he  $\frac{g}{2}$  con ib e o co n e fac al hinking  $\frac{g}{2}$  (Gome Belda ain,

Edinb gh Handedne<sub>s</sub>. In en o (EHI) o de e mine<sub>s</sub> eng h of handedne<sub>s</sub>, he c en Me = 77.5 ± 4.2 ed. Beca<sub>s</sub> é he EHI ± 4.2 co ed in inc emen<sub>s</sub> of e, a ici an<sub>s</sub>' ab<sub>s</sub> ol e<sub>s</sub> co ± of 80 and highe e e con<sub>s</sub> ide ed o be<sub>s</sub> ong handed and ab<sub>s</sub> ol e<sub>s</sub> co ± of 75 and lo e e e e con<sub>s</sub> ide ed o be mi ed-hande<sub>s</sub>. The c en<sub>s</sub> d con<sub>s</sub> i ed of 30 mi ed-hande<sub>s</sub> and 32<sub>s</sub> ong-handed<sub>s</sub> (onl one<sub>s</sub> ongl lef-handed<sub>s</sub> co e = -100).

## 2.2. Materials/apparatus

An ada a ion of he Al e na e U<sub>s</sub> T<sub>e</sub> (Chamo o-P emz ic, 2006) ± 4.2 ed o mea<sub>s</sub> e c ea i i . Thi ada a ion con<sub>s</sub> i ed of 20 common i em<sub>s</sub> (e.g. a e-cl<sub>s</sub>, encil<sub>s</sub> hoe, fo ll li<sub>s</sub> ee A endi A). We ed 15 i em<sub>s</sub> f om he o iginal Al e na e U<sub>s</sub> T<sub>e</sub> (Ch i eq en e al, 1960) and e f om a common o d bank (Snodg & Vande a , 1980). Each i em<sub>s</sub> cen e ed a he o of an 8.5" × 11" hee of hi e com e a e, ed in 16 . Tim<sub>s</sub> Ne Roman fon . The common<sub>s</sub> e a ea ed in a en he ne o each i em<sub>s</sub>. P e- e i em<sub>s</sub> incl ded e i em<sub>s</sub> in ed in a bookle i h a i le age ha d<sub>s</sub> la ed he in ed in c ion in 16 . Tim<sub>s</sub> Ne Roman fon . Pg - e i em<sub>s</sub> incl ded he emaining 15 i em<sub>s</sub> in ed in a<sub>s</sub> e a a e bookle, al o i h a i le age con aining he in ed in c ion . To a oid an o de effec<sub>s</sub> ha migh be im q ed b an<sub>s</sub> eci c i em<sub>s</sub>, o<sub>s</sub> e a a e e<sub>s</sub> ion<sub>s</sub> of he e- e and q - e e e c ea ed, and i em<sub>s</sub> e e andoml o de ed i hin each.

R<sub>e</sub> on<sub>s</sub> on he Al e na e U<sub>s</sub> T<sub>e</sub> e e<sub>s</sub> co ed on e diffe - en<sub>s</sub> b<sub>s</sub> co ± : (a) enc , indica ed b he o al n mbe of e<sub>s</sub> li<sub>s</sub> ed e i em<sub>s</sub> (ega dl<sub>s</sub> of' ali 'o a o ia eng<sub>s</sub>); (b) o ignali , indica ed b he n mbe of e<sub>s</sub> on<sub>s</sub> o ided b 0 5% f a ici an<sub>s</sub> (3 oin<sub>s</sub>), 6 10% (2 oin<sub>s</sub>) o 11 15% (1 oin<sub>s</sub>) of all a ici an<sub>s</sub> in he am le; (c) amo n of de ail o elabo a ion o ided fo each<sub>s</sub> e (on a 0 5 oin<sub>s</sub> cale); (d) e ibili o he n m-

c ea i e ad an age, and he he c ea i i a diffe en iall affec ed e-and q mani la ion, he e<sub>4</sub> b<sub>5</sub> co e of he Al e na e U e T<sub>6</sub> l enc , de ail, o iginali , ca ego ical d<sub>7</sub> inc i ene<sub>8</sub> and a o ia ene<sub>9</sub> ), e e<sub>10</sub> bmi ed o a 2 (Condi ion: con ol, bila e al EM)×2 (Handedne<sub>11</sub> : mi ed, e<sub>12</sub> ong)×(2)(T<sub>13</sub> : e, q )mi ed fac o ial MANOVA. M l i a ia e e<sub>14</sub> e-ealed a igni can main effec fo Handedne<sub>15</sub> (Wilks'  $\Lambda = .779$ , F(5, 54) = 3.06, p = .017, ( $\eta^2 = .221$ ) and T<sub>16</sub> (Wilks'  $\Lambda = .735$ , F(5, 54) = 3.89, p = .004, ( $\eta^2 = .265$ ) hen he de enden a iable a e linea l combined ac q<sub>17</sub> all ial . No main effec fo Condi ion (Wilks'  $\Lambda = .959$ , F < 1), o in e ac ion of Handedne<sub>18</sub> × T<sub>19</sub> (Wilks'  $\Lambda = .907$ , F < 1), Handedne<sub>20</sub> × Condi ion (Wilks'  $\Lambda = .978$ , F < 1), T<sub>21</sub> × Condi ion (Wilks'  $\Lambda = .947$ , F < 1), o Handedne<sub>22</sub> × Condi ion × T<sub>23</sub> (Wilks'  $\Lambda = .927$ , F < 1) e e ob<sub>24</sub> e ed fo he linea l combined b<sub>25</sub> co e . Uni a ia e ANOVA<sub>26</sub> al o e-ealed no igni can diffe ence fo T<sub>27</sub> fo he e<sub>28</sub> b<sub>29</sub> co e , gge ing ha he main effec in he m l i a ia e e<sub>30</sub> of e<sub>31</sub> . q - e ob<sub>32</sub> e ed o be an o e all ac ice effec ha i no e- ci c o an of he indi id al<sub>33</sub> b<sub>34</sub> co e .

### 3.3. Handedness findings for individual sub-scores of the Alternate Uses Test (post circle task)

The anal<sub>35</sub> e en ed in hi ec ion a e ba ed on a ici an<sub>36</sub>' e op e o e all 15 ial of he Al e na e U e T<sub>37</sub> k fo each<sub>38</sub> b<sub>39</sub> co e. Uni a ia e e<sub>40</sub> indica e ha mi ed-hande<sub>41</sub> ho ed g ea e l enc (M = 3.09, SE = .19) han<sub>42</sub> ong-hande<sub>43</sub> (M = 2.44, SE = .18), F(1, 58) = 6.15, p = .016, ( $\eta^2 = .096$ ); mi ed-hande<sub>44</sub> (M = 2.45, SE = .142), ho ed g ea e ca ego ical d<sub>45</sub> inc i ene<sub>46</sub> in hei an<sub>47</sub> han<sub>48</sub> ong-hande<sub>49</sub> (M = 1.67, SE = .13), F(1, 58) = 15.576, p < .001, ( $\eta^2 = .21$ ); mi ed-hande<sub>50</sub> (M = 2.70, SE = .16) had mo e a o ia e e<sub>51</sub> on<sub>52</sub> han<sub>53</sub> ong-hande<sub>54</sub> (M = 1.84, SE = .15), F(1, 58) = 14.40, p < .001, ( $\eta^2 = .20$ ); and mi ed-hande<sub>55</sub> (M = 3.35, SE = .28), ho ed mo e o iginali han<sub>56</sub> ong-hande<sub>57</sub> (M = 1.84, SE = .27), F(1, 58) = 13.80, p < .001, ( $\eta^2 = .19$ ). Mi ed-hande<sub>58</sub> (M = 2.5, SE = .13) e e ma ginall highe han<sub>59</sub> ong-hande<sub>60</sub> (M = 2.1, SE = .18) on he de ail<sub>61</sub> b<sub>62</sub> co e, F(1, 58) = 3.64, p = .06, ( $\eta^2 = .06$ ). Th<sub>63</sub> e e l<sub>64</sub> o he h o h<sub>65</sub> ha mi ed-handed indi id al o ld demor a e inc ea ed c ea i i on he e indi id al<sub>66</sub> co e han<sub>67</sub> ong-hande<sub>68</sub>.

Addi ionall , a priori gge ha he highe c ea i i of mi ed-hande<sub>69</sub> com a ed o<sub>70</sub> ong-hande<sub>71</sub> a d i en<sub>72</sub> olel b diffe ence in he con ol g o , b no he bila e al EM g o . Com a i op be een mi ed and<sub>73</sub> ong hande<sub>74</sub> in he con ol g o (no bila e al EM) e ealed diffe ence on all e<sub>75</sub> b<sub>76</sub> co e of c ea i i l enc , F(1, 28) = 4.2, p = .05,  $\eta^2 = .13$  (M<sub>mi ed</sub> = 3.05, SE = .24; M<sub>ong</sub> = 2.3, SE = .26); de ail, F(1, 28) = 5.4, p = .03,  $\eta^2 = .16$  (M<sub>mi ed</sub> = 2.54, SE = .17; M<sub>ong</sub> = 1.95, SE = .18); o iginali , F(1, 28) = 9.14, p = .005,  $\eta^2 = .25$  (M<sub>mi ed</sub> = 3.06, SE = .39; M<sub>ong</sub> = 1.03, SE = .42); ca ego ical d<sub>77</sub> inc i ene<sub>78</sub> , F(1, 28) = 9.46, p = .005,  $\eta^2 = .25$  (M<sub>mi ed</sub> = 2.4, SE = .20; M<sub>ong</sub> = 1.5, SE = .21); and a o ia ene<sub>79</sub> , F(1, 28) = 9.5, p = .005,  $\eta^2 = .25$  (M<sub>mi ed</sub> = 2.75, SE = .22; M<sub>ong</sub> = 1.75, SE = .23).

Th<sub>80</sub> e diffe ence be een<sub>81</sub> ong and mi ed-hande<sub>82</sub> di a - ea ed fo he bila e al EM g o fo l enc (F < 1), de ail (F < 1), o iginali [F(1, 30) = 2.06, p = .16], ca ego ical d<sub>83</sub> inc i ene<sub>84</sub> [F(1, 30) = 3.08, p = .09], and a o ia ene<sub>85</sub> [F(1, 30) = 2.6, p =

fo ca ego ical  $d_{ij}$  inc i eng $\zeta$ ,  $F(1, 30) = 4.71$ ,  $p = .04$ ,  $\eta^2 = .14$  ( $M_{bila e alEM} = 2.22$ ,  $SE = .20$ ;  $M_{con ol} = 1.56$ ,  $SE = .23$ ). No condition difference between  $d_{ij}$  of mi ed-handicapped ( $F < 1$ ), la  $d_{ij}$  of mi ed-handicapped ( $F < 1$ ), or la  $d_{ij}$  of long-handicapped ( $F \leq 1$ ).

Taken together, he  $d_{ij}$  of long-handicapped children had higher bilaterality than the other two groups. There was no significant difference between the two groups of handicapped children. The effect of long-handicap on  $d_{ij}$  was significant ( $F = 15.00$ ,  $p = .001$ ). There was no significant interaction between condition and age ( $F = 1.00$ ,  $p = .39$ ), sex ( $F = 0.00$ ,  $p = .99$ ), or sex by condition ( $F = 0.00$ ,  $p = .99$ ).

ion. Ho e e , fo he ca ego ical di inc i ene a ible, onl T ia 1 3 ( e o ed abo e) eached igni cance, and T ia 4 6 e e ma ginall igni can ,  $F(1, 30) = 3.6$ ,  $p = .06$ . T ia 7 9 [F(1, 30) = 2.4,  $p = .13$ ], 10 12 [F(1, 30) = 2.5,  $p = .11$ ], and 13 15 ("la e ia , e o ed abo e) e e no igni can ( see Fig. 3). Thi gge ha he effec of bila e al EM on o iginali of ong-hande ma la o 9 min befo e i di i a . B , he effec of bila e al EM on ca ego ical di inc i ene la a le 3 min and ma be o 6 min ( see Fig. 2 and 3, and Table 2).

While igni can diffe enc be een con ol and bila e al EM condion of ong-hande e e onl ob e ed fo he o iginali ( o ia 6 9) and ca ego ical di inc i ene ( o ia 3) co , addi ional anal ealed gene al do n a d linea enq in he bila e al EM condion ac q he e ial inc emen fo a o ia ene  $F(1, 17) = 8.03$ ,  $p = .01$ , o iginali ,  $F(1, 17) = 8.2$ ,  $p = .008$ , and ca ego ical di inc i ene ,  $F(1, 3$

B  $\geq$  galo , 2006) ob e ed bila e al EEG ac i i ela ed o o iginal-i co e on a eme e- $\ddot{\text{a}}$  ocia e k. The a e g ob e ed b Ra mniko a and colleag e al o gge ed ha he hemi he e ma be in ol ed in diffe en oce e ha con ib e o o iginali ch a cained a en ion, o king memo , and diff e ac i aion of al e na e o d meaning and ela ion hi . In addi ion, he c ea i i con c of ca ego ical di inc i ene ma al o ake ad an age of eciali a ion of he lef and igh hemi he e . The LH i a ic la l ell i ed oca ego ical oce ing he ea he RH a ea o be a ic la l ell i ed o iden if ing m l i le ca ego ical membe hi i ho he abili o di ing i h he mg ele an ca ego (Chia ello & Richa d , 1992; Chia ello e al , 1992; Ince & Ch i man, 2002). Th , ec i men of LH abili ie fo iden i ca ion of eci c a ego ie and RH abili ie fo m l i le ca ego ie ma gi e i e o a combined ad an age fo ca -ego ical di inc i ene co . The nding of Bech e e a e al . (2004) al o gge ha he LH i in ol ed in ca ego ical di inc i ene (e med flexibility b hem). We gge ha o iginali and ca ego ical di inc i ene e on e e facili a ed b IHI beca e he in ol e bo h LH and RH oce , and ha IHI ill ha e facili a i effec on an a k ha e i e bi-hemi he ic con ib ion . Thi ha al o been o q ed and o ed b Le al . (2008).

E en ho gh o iginali and ca ego ical di inc i ene do no a ea o el on he ame oce e o ne al b a e , e a e no gge ing ha bila e al EM l in a id ead, non eci c ac i a ion of he ce eb al hemi he e . Ra he , o nding

g en e idence o he con a beca e a o ia ene enc , and de ail, e la gel naffec ed b he bila e al EM mani la ion. Al ho gh io e ea ch i e limi ed, he e h ee e on e ma be mo e effec i el oce ed nila e all , i hin he LH o RH. Bo h e bal enc (Baldo, Sch a z , Wilkin , & D onke , 2006) and a o ia ene (To ance & Ho ng, 1980) ma be elai el g ic ed o LH oce . Con e el , abili o e o i al de ail (Ke inge & Choi, 2009) and gene a e de ailed i al image a ea o be mo e elian on RH oce (G a ini e al , 2008; S ide ka a, Ta a no a , & Ko hed b , 2006), and ma be analogo o he de ail meq e in o d . If bila e al EM gene a ed non eci c ac i a ion of bo h hemi he e , o con ol g o o ld ha e e hibi ed lo e co e on each of he e b co e . O nding ai e he Q ibili ha onl ca ego ical di inc i ene and o iginali e e affec ed b he EM mani la ion beca e he e beha io can bene f om combined LH and RH oce , he ea a o ia ene , de ail, and enc ma be mo e elian on nila e al oce .

In e e ingl , i ha been o q ed ha bila e al EM ma enable g ea e acce o RH oce (Ch i man & Po e , in ), and o ob e a ion of a ma ginal de ail ad an age ( $p = .06$ ) fo bila e al EM a ici an doq no nde mine hi Q -ibili . B e al o ecogni e ha io e ea ch on hemi he ic a mme ie fo gene a ing de ail d ing i al image i a e , h limi ing o ec la ion . E en ill, if he bila e al EM a k e -led in a gene ali ed ac i a ion of bo h hemi he e , hen ong-hande in o d ho ld ha e (1) ho n an im o e men in he EM g o o e he con ol fo enc , de ail, and a o ia ene ; o (2) ma ched he mi ed-hande . In ead, he mi ed-hande o e fo med hem in he con ol and he bila e al EM g o , and o e a e e onabl con den ha he effec i a k eci c.

We al o ec ha he IHI of mi ed-hande i ali a i el diffe en f om he IHI facili a ed b bila e al EM beca e he mani la ion did no aje all e b co e of ong-hande o le el e i alen i h mi ed-hande . While leng h e lan a ion of he mi ed-hande ad an age fo de ail, enc , and a o ia ene a be ond he co e of hi a e , one Q ibili i im l ha he ba ic ana omical diffe ence in he i e of he co -

callq m be een ong and mi ed-hande (D ie en & Ra , 1995; Habib e al , 1991; Wi el on & Gold mi h, 1991) doq no change follo ing an EM a k. The la ge co callq m ma gi e he mi ed-hande a mo e gene ali ed ad an age on he mea e e g e ed. We eadil ackno ledge, ho e e , ha he li e a e i e le e i h incop i en nding in o of a ela ion hi be een handedne and callq al i e. The co callq m clea l facili a e ap fe of info ma ion be een he hemi he e , b i ma al o e e o ed ce in e fe ence be een he hemi he e . Recen o k b Welcome e al . (2009) gge ha in mi ed-handed malg a la ge co callq m ma facili a e in e a ion, b in mi ed-handed female i ma minimi e in e fe ence. In o d , he aici an e e la gel female, and o he mi ed-handed ad an age fo de ail, enc , and a o ia ene ma lec minimi ed in e fe ence fo he e q ed nila e al oce .

So, hen, he e ion emaiq : Wha change doq a bila e al EM a k ind ce in he b ain? Al ho gh he no ion of a cen al e ec i e in he mind ma ielf be o e a ed, e o q e ha bila e al e e mo emen e e o ac i a e he ne al b a e go e ning me acon ol oce ha di ec a k eci c oce ing (fo e ie of me acon ol ee Hellige, 1995). Loh e al . (2006) al o gge ha me acon ol oce a e he oo of IHI. The o k of Ko niq e al . (2006) gge he loc of hi me acon ol mechani m fo c ea i i ma be he an e io cing la eco e (ACC), b f e ne oimaging e ea ch ma be nece a o de e mine he ela ion hi be een bila e al EM and he ACC.

Al ho gh e did no di ec l meq e he effec of bila e al EM on hemi he ic ac i i , o nding add o a la gel con i -en e of beha io al and h iological nding f om a io labo o a i g indica ing ha bila e al EM e e bila e al effec on hemi he ic oce ing. Po e e ic ooa

he e bal LH<sub>i</sub> he ca<sub>e</sub> e of bila e al ac i i . In addi ion o he  
bila e al a e<sub>e</sub> of ac i i e o ed b Folle and Pa k (2005)  
ho il<sub>i</sub> ed ic e<sub>e</sub> im li and allo ed fo<sub>e</sub> a iai mani la ion  
of hq e ic e<sub>e</sub> befo e gi ing a e bal e<sub>e</sub> on e, a io<sub>e</sub> c ea i i  
a<sub>k</sub> ha e been a<sub>e</sub> ocia ed i hac i i in LH f on al and em e o  
a ie al<sub>e</sub> c e<sub>e</sub> in ol ed in<sub>e</sub> a iai e ce ion of objec<sub>e</sub> (J ng-  
Beeman e al., 2004



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