Does the handedness continuum capture individual variations in the lateralization of cognitive functions?

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1 Introduction

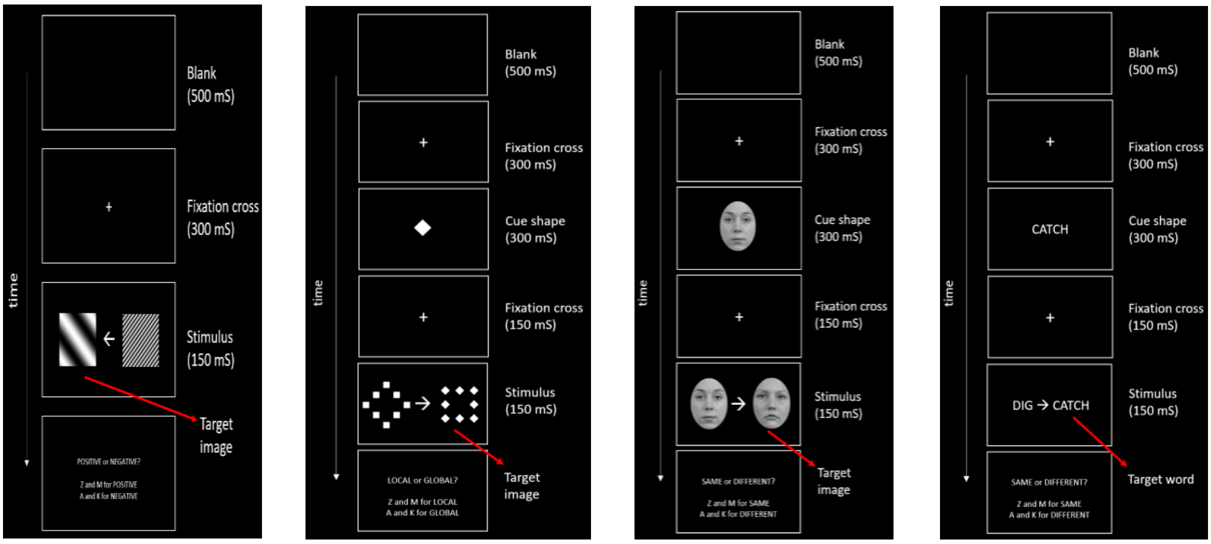
Structural (cortical surface area, grey matter volume, and cortical thickness) and functional asymmetry (hemispheric specialization) of brain hemispheres are fundamental characteristics of the human brain (Ocklenburg & Gunturkun, 2012). While perceptual information is processed in both hemispheres, certain functions show preferential processing in one hemisphere in the typical right-handed population (e.g., relatively high spatial frequency (HSF) and word/language processing are left-lateralized. Relatively low spatial frequency (LSF) processing and face/visuospatial attention are right-lateralized (Brederoo et al., 2019).

Most lateralization literature has either excluded left-handers due to their higher variability or failed to control the degree of handedness, resulting in discrete categorization. None, to our knowledge, has attempted to capture the entire handedness continuum to study lateralization patterns in healthy individuals. We, thus, aimed to look for a continuum of individual variations in lateralization of cognitive functions in tasks varying in the complexity of visual information processing along the handedness spectrum. We expected to observe a moderate correlation between handedness and laterality index irrespective of the task.

In Experiment 1, we examined the lateralization of the lowest level of visual information processing – namely, the spatial frequency content (magnocellular and parvocellular projections of retinal ganglion cells showing preferential processing of LSF and HSF, respectively, Kauffmann et al., 2014). Experiment 2 looked at visual attention (global-local task) processes that depend on the visual scene's spatial frequency content. With experiments 3 (Face matching task) and 4 (Word matching task), we tried to capture a higher level of processing in the visual hierarchy.

2 Methods

We used a divided visual half-field paradigm, with bilateral stimulus presentation with a central arrow pointing towards the target. Depending upon the task, participants had to press the 'z' and 'm' keys or the 'a' and 'k' keys using both hands to respond to the target image, thus capturing bimanual responses. The experiments were created on Psychopy builder and customized with code snippets.



In E1, participants judged the orientation (positive or negative) of the spatial gratings from two sets of spatial frequency (low SF: 0.5,0.6,0.7,0.8 and high SF: 5,6,7,8, all values in cpd). In E2, the task was to judge the level (global or local) at which a cue shape appeared. To remove any attention bias induced by the cue to either level, the size of the cue shape was the average size of local and global shapes. In E3, the task was to report the match between the cued face and the target face. Similarly, in E4, the task was to report the match between the cue word with the target word. Participants were asked to respond as fast as possible and as accurately as possible.

Participants were recruited through a modified Edinburgh handedness inventory, controlling for the degree of handedness, thus ensuring a uniform distribution of handedness scores of our participants. 63 participants were recruited, with handedness scores ranging between -1 to +1 (M= -0.06, SD =0.62). We used a 3 - SD cut-off in reaction times at the trial and population levels to capture maximum variation in our data. The laterality index was measured by subtracting reaction time in the left (LVF) and right visual field (RVF). LVF-

RVF > 0 indicated a preference for the left hemisphere (LH), whereas LVF-RVF < 0 showed a right hemisphere (RH) preference

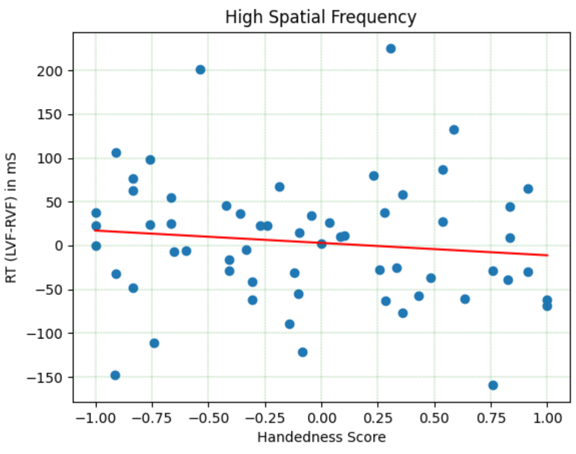
3 Results

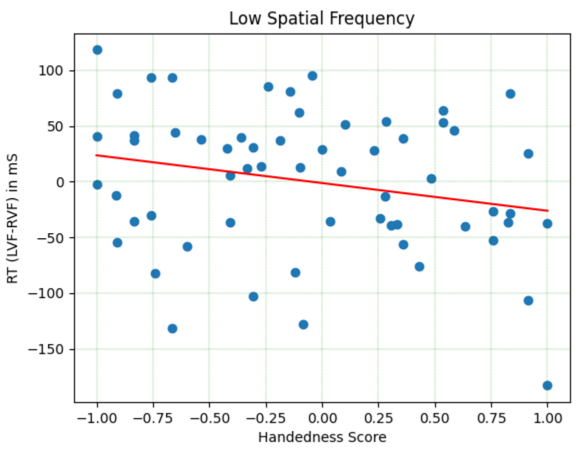
In E1, neither LSF nor HSF processing was significantly associated with handedness [LSF: r(59) = -0.24, p=.068, HSF: r(59) = -0.12, p=.370]. In E2, performance on both global and local tasks was significantly associated with the degree of handedness [Global: r(58) = -0.28, p=.029; Local: r(58) = -0.28, p=.034]. Similarly, performances with face–matching (E3) and word–matching (E4) tasks were significantly correlated with the degree of handedness Face: r(54) = -0.30, p=.023; Word – r(56) = -0.28, p=.038].

Task	E1 – LSF	E1 – HSF	E2 – Global	E2 – Local	E3 – Face	E4 – Word
n	60	60	59	59	55	57
r	-0.24	-0.12	**-0.28**	**-0.28**	**-0.30**	**-0.28**
p	.068	.370	**.029**	**.034**	**.023**	**.038**
CI	[-0.46, 0.02]	[-0.36, 0.14]	[-0.50, -0.03]	[-0.50, -0.02]	-0.53, -0.04]	[-0.50, -0.02]

Table 1: Correlation statistics

No population-level lateralization of spatial frequency processing was observed (laterality indices were distributed around 0, irrespective of handedness). Comparing left-handers (handedness score -1 to -0.33) with right-handers (handedness score 0.33 to 1) failed to show any significant difference in lateralization of spatial frequency processing.

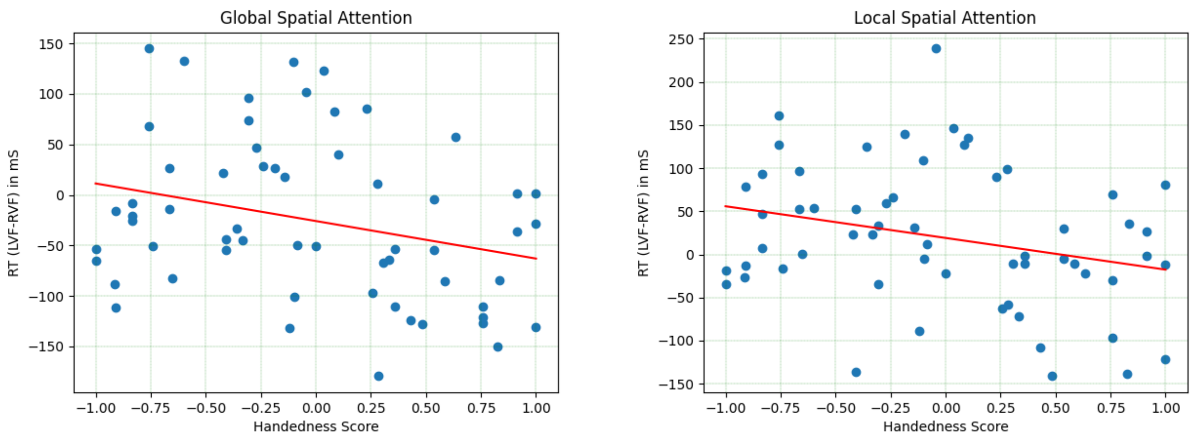




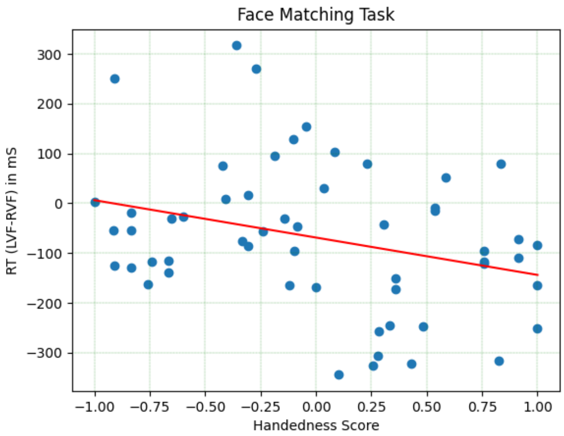
While there was no clear population-level lateralization of global and local processing, group comparison between left and right-handers revealed significant differences. We hypothesized that right-handed participants have RH lateralization for global – processing and a relative LH specialization for local processing. Conversely, for left-handed participants, one expected possible reversal of the said pattern based on the spatial frequency demands of global and local processes (Brederoo et al., 2020).

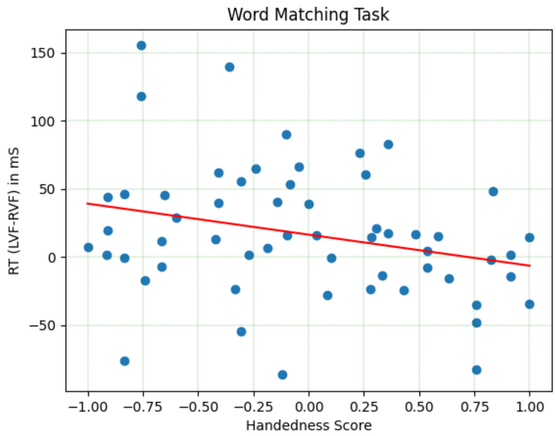
However, contrary to our hypothesis, we found that local processing was right-lateralized in right-handers (M=-35, SD=65). Moreover, left-handers showed an oppositive pattern (i.e., right hemisphere preference, (M=35, SD=69) for local processing, suggesting the possibility of reversal of processing of local processing as a function of handedness, t(35)=3.16, p<0.005, (as reported by Mevorach et al., 2005).

While we were able to replicate the early finding by Goodarzi et al., 2005 that the left-handers (M=-16, SD= 67) were slower than right-handers (M=-71, SD = 59) in processing global information in the RH, t(35)=2.71, p<.05, we could not observe any reversal of global processing in left-handers.



Interestingly, for experiments 3 & 4, we observed a population-level right-lateralization of face processing and left-lateralization of word processing. However, the lateralization for face and word processing varied as a function of the degree of handedness, suggesting that individuals may vary in lateralization patterns along the handedness continuum. Comparing left-handers (M=-23, SD=132) with right-handers (M=-124, SD=116) revealed significant differences in face matching task in the right hemisphere, t(32)=2.67, p<.05. Similarly, left-handers (M=32, SD=56) were significantly different from right-handers (M=-4, SD=37), $t(32)=2.52$, $p<.05$ in processing words in the left hemisphere.





	E1 – LSF	E1 – HSF	E2 – Global	E2 – Local	E3 – Face	E4 - Word
LHa: n (M, SD)	22 (10, 62)	22 (18, 73)	20 (-16, 67)	20 (35, 69)	17 (-23, 132)	19 (32, 56)
RHa: n (M, SD)	18 (-20, 66)	18 (-12, 71)	18 (-71, 59)	18 (-35, 68)	17 (-124, 116)	18 (-4, 37)
Diff – CI, p	[-10, 72], .13	[-16, 76], .19	[14,97], **.01**	[15,106], **.01**	[14,188], **.02**	[4,68], **.03**

Table 1: Left vs. right-handers - Group difference in laterality index

4 Discussion

Our current study looked at lateralization patterns for increasingly complex levels of visual information processing as a function of the participants' handedness. We found a significant association between hemispheric specialization and handedness in the global-local, face, and word tasks but not in spatial frequency tasks. To an extent, we did demonstrate that participants' hemispheric specializations for specific types of information processing might vary across the handedness spectrum.

Given that the RH and LH preferentially process HSF and LSF, respectively, we had expected to observe lateralized spatial frequency processing. Since our task was to detect the orientation of the grating, the failure in capturing the lateralized spatial frequency processing could be due to this indirect way of measuring spatial frequency processing. The reversed lateralization of local processing suggests a feasible hypothesis that underlying HSF could also be reversed in the left-handers; however, the lack of reversal of global processing complicates a symmetric model of global-local lateralization and hence, should be studied in detail.

The word and face processing depends on the HSF and LSF information, respectively. The observed LH preference for word and RH preference for face processing aligns with the findings of Brederoo et al., 2020 that the hemispheric preference for higher-level functions reflects lateralization of lower-level HSF and LSF information.

Overall, the current study provides some initial evidence that at the population level, lateralization patterns could vary across the handedness continuum; thus, we could benefit from using the handedness continuum in lateralization studies. Improved experimental designs and better sample sizes could provide more information about the lateralization patterns of lower-level spatial-frequency processing, wherein we failed to find a significant correlation.

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