



## Review

## Cognitive benefits of right-handedness: A meta-analysis

Metten Somers<sup>a,\*</sup>, Laura S. Shields<sup>b</sup>, Marco P. Boks<sup>a</sup>, René S. Kahn<sup>a</sup>, Iris E. Sommer<sup>a</sup><sup>a</sup> Brain Center Rudolf Magnus, Department of Psychiatry, University Medical Center Utrecht, Utrecht, The Netherlands<sup>b</sup> Faculty of Earth and Life Sciences, VU University Amsterdam, Amsterdam, The Netherlands

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## ABSTRACT

Hand preference – which is related to cerebral dominance – is thought to be associated with cognitive skills; however, findings on this association are inconsistent and there is no consensus whether left- or right-handers have an advantage in either spatial or verbal abilities. In addition, it is not clear whether an interaction between sex and hand preference exists in relation to these cognitive abilities. As these matters are relevant from a neurodevelopmental perspective we performed a meta-analysis of the available literature. We searched PubMed and Embase, and included 14 studies (359,890 subjects) in the verbal ability meta-analysis and 16 studies (218,351 subjects) in the spatial ability meta-analysis. There was no difference between the full sample of left and right-handers for verbal ability, nor was there a hand preference-by-sex interaction. Subgroup analysis of children showed a small right-hand benefit. Our results further revealed a modest but significant effect favouring right-handedness for overall spatial ability, which was more pronounced when analysis was restricted to studies applying the mental rotation test. We could not identify a specific interaction with sex. Our results indicate that there is a small but significant cognitive advantage of right-handedness on spatial ability. In the verbal domain, this advantage is only significant in children. An interaction effect with sex is not confirmed.

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\* Corresponding author at: Brain Center Rudolf Magnus, Department of Psychiatry, University Medical Center Utrecht, A01.4.68, PO Box 85500, 3508 GA Utrecht, The Netherlands. Tel.: +31 88 7556370; fax: +31 88 7555487.

E-mail address: [M.Somers@umcutrecht.nl](mailto:M.Somers@umcutrecht.nl) (M. Somers).

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## 1. Introduction

Hand preference or ‘handedness’ refers to the phenomenon that most humans use either the right or left hand for unimanual actions, such as writing. Across societies, the vast majority of individuals is right handed and in most countries the prevalence of left-handedness is estimated to be roughly 10 per cent (Gilbert and Wysocki, 1992; McManus, 2009; Peters et al., 2006). Left-handedness has never gone extinct, nor has it reached a majority in any population studied. There is evidence that the frequency of left-handers has been relatively stable at least since the Palaeolithic period (35,000–10,000 YBP) (Faurie and Raymond, 2004). A sex-difference in handedness is observed, showing a 25% higher prevalence of left-handedness in males (Sommer et al., 2008).

The origins of left-handedness have been studied extensively. Several mechanisms have been investigated, including pre-natal testosterone levels (Geschwind and Galaburda, 1985a,b,c; Medland et al., 2005; Witelson and Nowakowski, 1991), birth trauma (Coren and Porac, 1980) and cultural influences (Medland et al., 2004). Further, genetic mechanisms have been shown to play a role in the development of hand preference, with heritability estimated at 25% (Medland et al., 2009). Always having been a minority, many tales have been told about left-handers.

Left-handedness has been argued to be both disadvantageous and advantageous in literature. For example, left-handedness has been commonly associated with more “sinister” characteristics such as criminal inclination (Bogaert, 2001; Green and Young, 2001), unusual sexual preferences (Bogaert, 2001; Ellis and Ames, 1989), dyslexia (Tønnessen et al., 1993) and stuttering (Kushner, 2012). Until a few decades ago, left-handed children in many societies were forced to use their right-hand for writing as left-handedness was considered an aberrant trait (Hugdahl et al., 1993). It has been suggested that left-handers are at an increased risk for accidents in Western societies (Daniel and Yeo, 1994; Halpern and Coren, 1991), because the industrial environments in these settings are designed for right-handers (Coren and Halpern, 1991; Porac and Cohen, 1981). The most notorious association with left-handedness, shorter life expectancy, was found to be an incorrect association (Aggleton et al., 1994; Hicks et al., 1994; McManus, 2009), as it was a subtle increase in the prevalence of left-handedness in the twentieth century, and not an earlier death, that has caused the relative paucity of elderly left-handers. In contrast to these (often false) accusations, several positive qualities have also been attributed to left-handedness. For example, the consistent presence of left-handedness over time and across societies has been attributed to an evolutionary benefit for this trait. One model to explain such a benefit is frequency dependent selection. This refers to an advantage of the minority group within a population due to a certain trait or skill. The advantage depends on the frequency of these individuals and disappears if their numbers increase (Vallortigara and Rogers, 2005). Raymond et al. proposed that left-handers have a frequency dependent advantage in fighting interaction, which may have resulted in increased fitness. Indeed, a higher proportion of left-handers was found in sports that reflected fighting interaction (Billiard et al., 2005; Raymond et al., 1996). Additional examples of a left-hand benefit include (inconsistent) findings of left-handers to be more talented in fast ball sports (Holtzen, 2000; Wood and Aggleton, 1989), have better musical

skills (Byrne, 1974; Oldfield, 1969) and higher income earnings compared to right-handers (Ruebeck et al., 2007).

Of particular interest is the possibility of a cognitive benefit for left-handers. For example, popular belief still holds the left-handed to be more intelligent and creative (see for example: <http://www.independent.co.uk/life-style/health-and-families/health-news/left-handers-more-creative-but-forgetful-710626.html> for an article in the press that describes great advantages of left-handedness). Within the cognitive domain, research from the fields of neuroscience and psychology has focused on the association of hand-preference with specific cognitive skills. Of all cognitive skills, spatial and verbal ability have been the most extensively investigated (e.g. Annett and Turner, 1974; Burnett et al., 1982; Crow et al., 1998; Hardyck et al., 1976; Mc Gee, 1976). However, the debate as to whether a difference between left and right-handers exists remains to be resolved, despite numerous studies comparing verbal and spatial abilities of left and right-handed individuals. The importance of this unresolved issue lies in the fact that conclusive results might shape policies related to handedness, for example with regard to in- or exclusion of left-handers in scientific research. Further, if left-handers do indeed show a specific cognitive benefit or deficit, this may have some implications; for example, in educational settings, it might be helpful to build in support structures to help left-handed children strengthen certain skills.

In most humans the neural representation of verbal and spatial ability is lateralized to either of the two cerebral hemispheres (Szafarski et al., 2006). This phenomenon, cerebral lateralization, correlates with hand preference, though this is not a strong association. Up to 95% of right-handed people display left-cerebral dominance for language functions (Szafarski et al., 2006). In left-handed individuals, about 75% show left-cerebral dominance, 10% show right dominance and 15% show a bilateral pattern of language lateralization (Jesús Pujol et al., 1999). Although the relationship between hand preference and spatial lateralization has not been extensively investigated (Jesús Pujol et al., 1999) a meta-analysis showed that the right-hemisphere controls spatial tasks in right-handers, while no hemispheric preference was found in left-handers (Vogel et al., 2003). The differences in lateralization patterns of cognitive functions may underlie a benefit or deficit pertaining to either spatial or verbal ability in left-handers.

Levy was the first to propose that left-handers may have a deficit in spatial function as measured by Performal IQ (PIQ) (Levy, 1969). She suggested that left-handers would have more right-hemispheric language function, which competes with spatial functions for neural resources in the right hemisphere, and consequently impedes spatial abilities. Several subsequent studies, however, were unable to replicate this finding (Briggs et al., 1976; Fagan-Dubin, 1974; Inglis and Lawson, 1984). Some studies found left-handers performing equally well as right-handers (Newcombe and Ratcliff, 1973), whereas other studies found left-handers having lower spatial, but higher verbal ability (McKeever, 1986). Most studies have assessed handedness as a dichotomous trait, but different associations emerge when hand preference is considered as a trichotomous trait (Peters, 1998) or as sub-classified trait as in the Annett 7–8 group model (Annett, 2004; Crow et al., 1998). For example, one study demonstrated that extreme left- and right-handers had lower spatial skills compared to mixed- and

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