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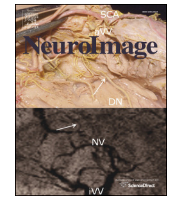

Review

The handyman's brain: A neuroimaging meta-analysis describing the similarities and differences between grip type and pattern in humans

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ABSTRACT

Background: Handgrip is a ubiquitous human movement that was critical in our evolution. However, the differences in brain activity between grip type (i.e. power or precision) and pattern (i.e. dynamic or static) are not fully understood. In order to address this, we performed Activation Likelihood Estimation (ALE) analysis between grip type and grip pattern using functional magnetic resonance imaging (fMRI) data. ALE provides a probabilistic summary of the BOLD response in hundreds of subjects, which is often beyond the scope of a single fMRI experiment.

Methods: We collected data from 28 functional magnetic resonance data sets, which included a total of 398 male and female subjects. Using ALE, we analyzed the BOLD response during power, precision, static and dynamic grip in a range of forces and age in right handed healthy individuals without physical impairment, cardiovascular or neurological dysfunction using a variety of grip tools, feedback and experimental training.

Results: Power grip generates unique activation in the postcentral gyrus (areas 1 and 3b) and precision grip generates unique activation in the supplementary motor area (SMA, area 6) and precentral gyrus (area 4a). Dynamic handgrip generates unique activation in the precentral gyrus (area 4p) and SMA (area 6) and of particular interest, both dynamic and static grip share activation in the area 2 of the postcentral gyrus, an area implicated in the evolution of handgrip. According to effect size analysis, precision and dynamic grip generates stronger activity than power and static, respectively.

Conclusion: Our study demonstrates specific differences between grip type and pattern. However, there was a large degree of overlap in the pre and postcentral gyrus, SMA and areas of the frontal–parietal–cerebellar network, which indicates that other mechanisms are potentially involved in regulating handgrip. Further, our study provides empirically based regions of interest, which can be downloaded here within, that can be used to more effectively study power grip in a range of populations and conditions.

Contents

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Introduction

Human beings are unique in their ability to grip objects using four fingers and an opposable thumb. Early in human evolution, *Homo habilis* (taken from Latin to mean 'able handyman') (Leakey et al., 1964) distinguished itself from other early hominids by its ability to use its hands with two advantageous grips: the power and precision grip (Napier, 1956; Young, 2003). The power grip (Fig. 1, A) has been extensively studied (Ehrsson et al., 2000; Goswami et al., 2011; Halder et al., 2006; Keisker et al., 2009, 2010; Kuhtz-Buschbeck et al., 2008; Muir and Lemon, 1983; Napier, 1956; Noble et al., 2011; Schmidt et al., 2009; Sclocco et al., 2012; Talelli et al., 2008; Ward et al., 2008) and is thought to have been selected for aggressive actions such as clubbing (Young, 2003). The precision grip (Ehrsson et al., 2000, 2001; Kuhtz-Buschbeck et al., 2001; Muir and Lemon, 1983; Napier, 1956; Neely et al., 2013; Sulzer et al., 2011) (Fig. 1, B) is used for actions requiring accuracy and was selected for actions such as spear throwing (Napier, 1956; Young, 2003), tool manufacturing (Marzke and Marzke, 2000) and tool use (Landsmeer, 1962; Young, 2003). These grips can be applied in either a dynamic or static pattern (Landsmeer, 1962). Dynamic handgrip is a series of intermittent or rhythmic forces whereas static is a fixed force. Despite the fundamental role of handgrip in human evolution (Napier, 1956; Young, 2003), a consensus of the neutral similarities and differences between them remains elusive. The brain mechanisms involved in hand movement have been recently reviewed (Hardwick et al., 2013; Prodoehl et al., 2009) but a meta-analysis of the brain's Blood Oxygen Level Dependent (BOLD) response associated with the grip type or pattern, using Activation Likelihood Estimation (ALE), a method of meta-analysis for functional magnetic resonance imaging (fMRI), has not been performed. fMRI measures the alteration of the magnetic field caused by an imbalance between oxy- and deoxyhemoglobin (Leslie and James, 2000) and the BOLD signal is thought to be a proxy for brain activity (Leslie and James, 2000).

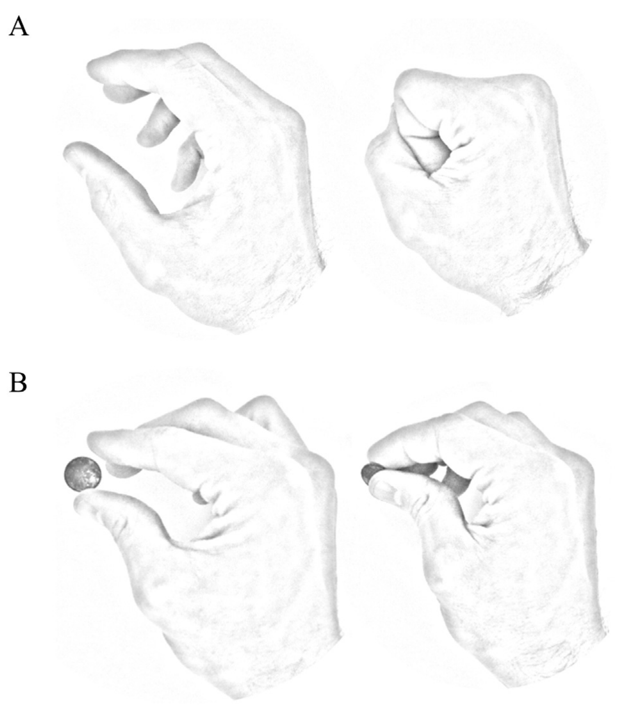

Fig. 1. Schematic of power (A) and precision (B) grips. The power grip is performed by flexing all digits around an object using little dexterity and typically generates more force than precision grip. On the other hand, the precision grip is performed using one or more fingers and a thumb with dextrous acuity and typically generates less force than power grip.

Previous research suggests that grip type (Kuhtz-Buschbeck et al., 2008) and pattern (Neely et al., 2013; Thickbroom et al., 1999) have differing brain activity. Indeed, power and precision grips are physiologically and anatomically different (Landsmeer, 1962); there are grip specific bone and muscular adaptations for each (Marzke and Marzke, 2000), both thought to be developed near the origin of hominid lineage (Young, 2003). The power grip requires a much larger proportion of extrinsic muscles, where as the precision grip relies more on intrinsic muscles (Long et al., 1970; Napier, 1956). Further, the application of these grips are primarily for force and precision, respectively, and thus the muscle volume, force and sensory feedback generated during power grip is greater than precision grip (Long et al., 1970); after

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