Bachelor Degree Project

BODY OWNERSHIP
An Activation Likelihood Estimation
Meta-Analysis

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Abstract

How is it that we feel that we own our body? And how does the brain create this feeling? By manipulating the integration of multisensory signals, researchers have recently begun to probe this question. By creating the illusory experience of owning external body-parts and entire bodies, researchers have investigated the neurofunctional correlates of body ownership. Recent attempts to quantitatively synthesize the neuroimaging literature of body ownership have shown inconsistent results. A large proportion of functional magnetic resonance imaging (fMRI) findings on body ownership includes region of interest (ROI) analysis. This analysis approach produces inflated findings when results are synthesized in meta-analyses. We conducted a systematic search of the fMRI literature of ownership of body-parts and entire bodies. Two activation likelihood estimation (ALE) meta-analyses were conducted, testing the impact of including ROI-based findings. When ROI-based results were included, frontal and posterior parietal multisensory areas were associated with body ownership. However, a whole-brain meta-analysis, excluding ROI-based results, found no significant convergence of activation across the brain. These findings highlight the difficulty of quantitatively synthesizing a neuroimaging field where a large part of the literature is based on findings from ROI analysis. We discuss the difficulty of quantitatively synthesizing results based on ROI analysis and suggest future directions for the study of body ownership within the field of cognitive neuroscience.

Keywords: Body ownership, fMRI, ALE meta-analysis, Region of interest, Multisensory integration

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Introduction

Self-consciousness, the experience that I am the subject, or a self, of a conscious experience, is a complex, multifaceted phenomenon. One fundamental aspect of self-consciousness is embodiment, the feeling of being localized within one's physical body (Arzy, Thut, Mohr, Michel, & Blanke, 2006; Legrand, 2006). Within the cognitive sciences, a growing number of researchers have adopted the viewpoint that the body has a central role in the shaping of the mind (Wilson, 2002). This has led to an increasing interest in the bodily foundations of self-consciousness and the view that studying these fundamental, or minimal, bodily forms of self-consciousness is a promising approach for a science of self-consciousness (Blanke & Metzinger, 2009; Gallagher, 2000). Bodily self-consciousness has been proposed to depend on at least three factors: body ownership (the experience that this is my body), self-location (the experience of being a body, situated in space), and first-person perspective (the experience of viewing the world from my body) (Blanke, 2012; Serino et al., 2013).

Body Ownership

Body ownership is the non-conceptual, ever-present sense that our body and body-parts belong to us (Braun et al., 2018; Gallagher, 2000). It is the sense that I experience this body as 'my' body. This ever-present sense of owning the body does, however, bring with it a series of methodological problems for studying body ownership scientifically. Experimental designs within the psychological sciences typically involve directly comparing two conditions, one where the investigated phenomenon is present, and one in which it is absent (Tsakiris, 2010). Early studies of body ownership were, due to this limitation, forced to focus on self-recognition in human and non-human primates (Jeannerod, 2003; Tsakiris, 2010). These experiments typically involved participants judging whether a body-part did or did not belong to them (e.g., van den Bos & Jeannerod, 2002). These experiments, therefore, captured the explicit judgement of body ownership, but not the subjective "feeling" of body ownership (Tsakiris, 2010).

Over the past 22 years, body ownership has been studied through perceptual illusion paradigms that alter the sense of ownership over the body (e.g., Petkova & Ehrsson, 2008) or individual body-parts (e.g., Botvinick & Cohen, 1998). These illusions lead to the feeling of owning an artificial body or body-part (see the following sections). The feeling of body ownership thus becomes altered, or abnormal. These experiments allow researchers to manipulate body ownership in a controlled setting. In the present thesis, body ownership is operationalized as the sense of body ownership over an external body or body-part, as compared with a control condition which does not

alter the sense of body ownership over that body or body-part. Hence, when we attempt to synthesize the functional magnetic resonance imaging (fMRI) literature of body ownership, we are analyzing the fMRI results of participants experiencing ownership over an external body or body-part.

The rubber hand illusion. In 1998, an experimental paradigm was developed that uses congruent multisensory stimulation to alter the experience of ownership over a body-part, which allowed researchers to manipulate the feeling of body ownership in a controlled manner for the first time (Botvinick & Cohen, 1998). In the rubber hand illusion, the participant's real hand is hidden from view, while he or she fixates on a realistic-looking rubber hand. The experimenter then strokes the fake hand and the real hand in spatiotemporal synchrony, using a brush. This leads to the feeling that the rubber hand is part of one's body (Botvinick & Cohen, 1998). Asynchronous visuo-tactile stroking of the rubber hand did not invoke this illusion (Botvinick & Cohen, 1998). The rubber hand illusion can be measured subjectively with questionnaires (Botvinick & Cohen, 1998), behaviourally through a "proprioceptive drift" of the location of the real hand towards the rubber hand (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005), or physiologically by the recording of skin conductance following a threat to the rubber hand (Armel & Ramachandran, 2003).

Studying which perceptual rules determine the induction of the rubber hand illusion has been an important goal of behavioural studies of body ownership (Ehrsson, 2020). Studies have shown that the rubber hand illusion depends on the temporal congruence of multisensory cues from the limb. This means that if stroking of the real and fake hands are asynchronous, no ownership of the hand will be experienced (Bekrater-Bodmann et al., 2014; Shimada, Fukuda, & Hiraki, 2009). The induction of the rubber hand illusion is further dependent on spatial congruence. If the fake rubber hand is stroked at a different location, placed in an anatomically implausible position, or placed far away, compared to the real hand, no illusion will be elicited (Ehrsson, 2020; Lloyd, 2007; Preston, 2013). Congruence of other stimulus features, such as texture (Ward, Mensah, & Jünemann, 2015) and shape (Tsakiris, Carpenter, James, & Fotopoulou, 2010) also influence the sense of ownership elicited by the rubber hand illusion. The fake hand needs to have a similar texture and appearance as a human hand for the illusion to be elicited. This research has resulted in a variety of different techniques and conditions used to induce the rubber hand illusion. Furthermore, the perceptual rules of the rubber hand illusion are similar to the spatial and congruence principles that determine multisensory integration in general (Ehrsson, 2020; Holmes & Spence, 2005; Stein & Stanford, 2008). These principles state that when multiple signals from multiple different sensory

modalities occur simultaneously (temporal principle) and in the same place (spatial principle), they will be integrated, leading to the experience of multisensory perceptual unity (Ehrsson, 2020).

        Multisensory integration. Multisensory integration refers to the process of integration, and potential conflict resolution, of sensory information, which generates a coherent perception of the world and the body (Tsakiris, 2010). The initial rubber hand illusion experiment highlighted the importance of successful integration of visuo-tactile sensory information for the sense of ownership over an external body part (Botvinick & Cohen, 1998). Since then, other versions of the rubber hand illusion, utilizing different sensory modalities to elicit the illusion, have been developed (e.g., Ehrsson, Holmes, & Passingham, 2005; Kalckert & Ehrsson, 2012; Limanowski & Blankenburg, 2016a), further highlighting the importance of multisensory integration over the importance of any single sensory modality in the experience of body ownership. Further multisensory bodily illusion paradigms have been developed to study not just the sense of ownership over a hand, but other body-parts and the entire body. Using virtual reality technology, synchronous or asynchronous visuo-tactile stimulation of the abdomen of a participant and a virtual body has been utilized in different experiments to induce the sense of ownership over an entire body, such as in the out-of-body illusion (Ehrsson, 2007), the full-body illusion (Lenggenhager, Tadi, Metzinger, & Blanke, 2007), and the body-swap illusion (Petkova & Ehrsson, 2008). In the enfacement illusion (Sforza, Bufalari, Haggard, & Aglioti, 2010), visuo-tactile stimulation of the face of a participant and that of another person leads to the illusory experience of ownership over the other person's face. The rubber foot illusion (Crea, D'Alonzo, Vitiello, & Cipriani, 2015) is an extension of the rubber hand illusion to the foot and has shown to induce an illusory sense of ownership over a rubber foot. While it has been argued that multisensory integration is not sufficient by itself for the ownership over body-parts and the entire body (Tsakiris & Haggard, 2005; Tsakiris, 2010, 2017), successful multisensory integration appears to play a crucial role in the sense of ownership (Blanke, 2012; Blanke, Slater, & Serino, 2015; Ehrsson et al., 2005; Serino et al., 2013; Tsakiris, 2010).

Neurofunctional Correlates of Body Ownership

        fMRI experiments have recently begun employing these bodily illusion paradigms, adapted for the scanner environment, to study the functional correlates of ownership over hands (Ehrsson, Spence, & Passingham, 2004), faces (Apps, Tajadura-Jiménez, Sereno, Blanke, & Tsakiris, 2015), feet (Matsumoto, Nakai, Ino, & Mitani, 2020), and the entire body (Petkova et al., 2011). Several studies have reported activity in premotor and posterior parietal areas (Ehrsson et al., 2005; Gentile, Guterstam, Brozzoli, & Ehrsson, 2013; Petkova et al., 2011), while others have not (Limanowski,

Lutti, & Blankenburg, 2014). Other areas activated in studies of body ownership include the insula (Apps et al., 2015; Limanowski et al., 2014), the lateral occipital cortex (Guterstam, Björnsdotter, Gentile, & Ehrsson, 2015), the parietal operculum (Gentile et al., 2013), the putamen (Petkova et al., 2011), and the cerebellum (Ehrsson et al., 2005; Preston & Ehrsson, 2016).

Region of interest analysis. fMRI studies of body ownership have commonly utilized region of interest (ROI) analysis, where the search for significance is limited to regions that are a priori hypothesized to be involved in body ownership. ROIs can be defined based on anatomy, previous literature, or a separate localizer scan (Poldrack, 2007). Compared with whole-brain (voxel-wise) analysis, where hypothesis testing is conducted simultaneously for each voxel in the whole brain and then corrected for multiple comparisons, ROI analysis can decrease the number of tests to as few as one (mean ROI activity between two conditions), or the analysis could be limited to those voxels inside the ROI (small-volume correction; Worsley et al., 1996). Due to the limited number of tests conducted, ROI analysis can be argued to provide increased statistical power compared to whole-brain analysis (Cremers, Wager, & Yarkoni, 2017; Saxe, Brett, & Kanwisher, 2006), but at the expense of using a less conservative threshold. ROI analysis is considered to be justified only when a strong a priori hypothesis exists (Poldrack, 2007). As neuroimaging studies of body ownership commonly hypothesize activation in the premotor cortex, intraparietal sulcus, and insular areas, these areas are commonly analyzed using an ROI approach (e.g., Bekrater-Bodmann et al., 2014; Brozzoli, Gentile, & Ehrsson., 2012; Ehrsson et al., 2005; Ehrsson et al., 2004; Gentile, Björnsdotter, Petkova, Abdulkarim, & Ehrsson, 2015; Limanowski & Blankenburg, 2016a; Limanowski et al., 2014; Petkova et al., 2011).

Synthesizing the literature. Individual neuroimaging studies, in general, suffer from low statistical power (Button et al., 2013; Carp, 2012b) and are heavily influenced by the analysis pipeline chosen by the researcher, which leads to low reproducibility (Carp, 2012a; Wager, Lindquist, Nichols, Kober, & Van Snellenberg, 2009). Synthesizing neuroimaging results through meta-analysis provides an approach for overcoming these limitations and is an important tool for resolving conflicting results within the neuroimaging literature (Müller et al., 2018).

Recently, three separate coordinate-based meta-analyses have been conducted on neuroimaging studies of body ownership (Grivaz, Blanke, & Serino, 2017; Salvato, Richter, Sedeño, Bottini, & Paulesu, 2019; Seghezzi, Giannini, & Zapparoli, 2019). While none of these meta-analyses focused solely on body ownership, all three meta-analyses compared the neurofunctional correlates of body ownership, resulting from separate meta-analyses of body ownership studies, with the

neurofunctional correlates of peripersonal space (Grivaz et al., 2017), sense of agency (Seghezzi et al., 2019), and interoception (Salvato et al., 2019).

Grivaz et al. (2017) conducted an activation likelihood estimation (ALE) meta-analysis of 17 functional imaging studies of body ownership. They found converging activation patterns within four clusters (Grivaz et al., 2017). Two clusters were located in bilateral parietal regions. Both parietal clusters were located mainly in the intraparietal sulcus, with the left cluster also including the primary somatosensory cortex and the superior parietal lobule, while the right cluster included the superior parietal lobule. A third cluster was located in the right prefrontal cortex, mainly in the ventral premotor cortex. The fourth cluster was located in the left anterior insula (Grivaz et al., 2017).

Seghezzi et al. (2019) conducted their conjunction analysis of body ownership and sense of agency using ALE, but for the separate meta-analysis of body ownership a hierarchical clustering analysis was used, from which the results were subsequently entered into a cluster composition binomial analysis (Cattinelli, Valentini, Paulesu, & Borghese, 2013; Seghezzi et al., 2019). This meta-analytical method is called "Clustering the Brain" (CluB; Berlingeri et al., 2019). 17 functional imaging studies were included in the analysis. Two clusters were found in the left hemisphere to be significantly associated with body ownership, one located in the inferior parietal lobule and one in the inferior occipital gyrus.

Salvato et al. (2019) conducted a meta-analysis using multilevel kernel density analysis (MKDA). 16 functional imaging studies of body ownership were included in their analysis. They found convergence of activation in six clusters, corrected for multiple comparisons. Two clusters were located bilaterally in inferior temporal regions, spanning to inferior occipital regions. One cluster was located in the left inferior parietal lobe, also including the postcentral gyrus and centred in the supramarginal gyrus. One cluster was located in the right precentral gyrus, one in the left fusiform gyrus, and one in the right cerebellar tonsil (Salvato et al., 2019).

Inconsistent findings. The different results obtained from three separate meta-analyses, published within two years from each other, are striking. Subjective choices such as selection of inclusion criteria and how to analyze the data can impact the results of a meta-analysis (Lakens, Hilgard, & Staaks, 2016; Palpacuer et al., 2019). As is the case with individual neuroimaging studies, meta-analytical methods provide a large degree of analytical flexibility. As for selection of inclusion criteria, two of the previously mentioned meta-analyses included studies based on both whole-brain and ROI analysis (Grivaz et al., 2017; Seghezzi et al., 2019), while one meta-analysis only included

studies based on whole-brain analysis (Salvato et al., 2019). The whole-brain meta-analysis conducted by Salvato et al. (2019) indicated a larger network of occipitotemporal, parietal, prefrontal, and cerebellar areas associated with body ownership, compared with the two previous meta-analyses. Interestingly, convergence of activation was found in premotor and intraparietal areas in all three meta-analyses. However, when only whole-brain results were included in the meta-analysis, no significant convergence of activation was found in the insula (Salvato et al., 2019).

Coordinate based meta-analyses, such as ALE and MKDA, test for convergence across experiments against a null-hypothesis of random spatial associations across the entire brain. This assumes that each voxel a priori has the same probability of being activated (Albajes-Eizagirre & Radua, 2018; Eickhoff, Bzdok, Laird, Kurth, & Fox, 2012). Inclusion of ROI analyses can, therefore, bias the results of the meta-analysis toward these regions, as the assumption of equal probability of activation for each voxel is violated (Müller et al., 2018). It is, therefore, possible that convergence in the insula found in two meta-analyses was the result of this bias. It is, however, important no note that excluding a large portion of the literature can instead lead to a bias against these particular areas, as studies showing their activation are excluded from the meta-analysis (Müller et al., 2018).

Aim and hypothesis. The present thesis aimed to quantitatively synthesize the fMRI literature on the sense of body ownership. We conducted a systematic literature search for fMRI experiments utilizing perceptual illusions to alter the sense of body ownership. Two ALE meta-analyses were conducted. The primary meta-analysis included results based on both ROI and whole-brain analyses. To assess the impact of including experiments based on ROI analyses, and thereby the use of different inclusion criteria, a secondary, whole-brain meta-analysis was conducted, where results from individual studies based on ROI analyses were excluded.

Due to the large proportion of fMRI studies of body ownership that have reported results based on ROI analyses, we hypothesized that the choice of inclusion criteria, in the form of inclusion or exclusion of results based on ROI analyses, has an impact on the meta-analytic results. If the results were largely driven by ROI analyses, this would raise questions about which conclusions can be made about the neurofunctional correlates of body ownership and why a less conservative threshold appears to be necessary to find activation in brain areas that are frequently hypothesized to be involved in body ownership.

Methods

Selection of Studies and Inclusion Criteria

A literature search was conducted to identify fMRI experiments investigating the neurofunctional correlates related to the sense of ownership of a body part or the whole body in healthy participants. PubMed, Web of Science, and Scopus were searched for relevant articles during February 2020, using the following search terms: ("fmri" OR "functional magnetic resonance imaging") AND ("ownership" OR "self*identification" OR "rubber*hand illusion" OR "full*body illusion" OR "body*swap illusion"). The search was restricted to articles published before February 19, 2020. Relevant titles and abstracts were evaluated for full-text screening. Full-text articles were then evaluated for inclusion based on predefined inclusion criteria (see below). Furthermore, additional references were obtained from two recent meta-analyses on the topic (Grivaz et al., 2017; Seghezzi et al., 2019) by evaluating articles that the authors identified for inclusion.

Experiments were included in the meta-analysis based on the following inclusion criteria:
1) It was conducted using fMRI.
2) It contained at least one contrast comparing body ownership to a control condition in a within-subject design.
3) The whole brain was covered during image acquisition (i.e. the field of view contained the whole brain).
4) Results were reported as coordinates in a standard stereotaxic reference space, either Montreal Neurological Institute (MNI) or Talairach. Statistical Parametric Mapping (SPM) and FMRIB Software Library (FSL) use MNI as their standard templates. Therefore, coordinates from studies using these programs, and which did not report a transformation from MNI to Talairach, were treated as MNI coordinates unless the use of a different template was explicitly stated (n=1).
5) All participants were adults and of a non-clinical population.
6) The articles were written in English and published in a peer-reviewed journal.

Data Extraction

The following information was manually extracted from each experiment: activation foci (peak coordinates), sample size, stereotaxic coordinate space used (i.e. MNI or Talairach), type of illusion, statistical contrasts, and statistical significance thresholds (see table 1 and appendix A). For articles that included more than one relevant contrast for the same group of subjects (e.g. Limanowski & Blankenburg, 2015), the coordinates from each contrast were pooled together into a single set of coordinates and treated as one experiment in the meta-analysis. In other words, only

one set of coordinates was used for each experiment to minimize the possibility that the meta-analytic results were influenced by within-group effects (Müller et al., 2018; Turkeltaub et al., 2011). One article included several separate studies (Petkova et al., 2011). As the three studies in this article consisted of three independent groups of subjects, they were treated as independent experiments, and thus not pooled together. In effect, this means that each subject-group was treated as one experiment (Turkeltaub et al., 2011).

Table 1

fMRI Studies Included in the Primary Meta-Analysis

Author and Year	Sample Size	Illusion	Contrast Description
Ehrsson et al. (2004)	18	RHI	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)
Ehrsson et al. (2005)	15	RHI	(illusion - asynchronous) + (illusion-incongruent)
Petkova et al. (2011)	26	BSI	Study 1: (Body Synch - Body Asynch) - (Wood Synch - wood Asynch)
	20	BSI	Study 2: (1PP Synch - 1PP Asynch) - (3PP Synch - 3PP Asynch)
	20	RHI	Study 3: (Attached hand Synch - Attached hand Asynch) - (Detached hand Synch - Detached hand Asynch)
Ionta et al. (2011)	22	FBI	Body by stroking interaction
Brozzoli et al. (2012)	16	RHI	(Synch first - Synch second) - (Asynch first - Asynch second)
Gentile et al. (2013)	15	RHI	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)
Guterstam et al. (2013)	14	RHI	Synchronous vs asynchronous inclusively masked with a synchronous versus incongruent condition
Limanowski et al. (2014)	20	RHI	Congruent vs incongruent spatial stimulation for RHI vs control object

Bekrater-Bodmann et al. (2014)	25	RHI	Sync vs async
Apps et al. (2015)	15	EFI	Congruency x synch interaction
Gentile et al. (2015)	16	FBI	Average decoding maps for synch vs async
Guterstam et al. (2015)	15	BSI	Sync vs async across positions
Limanowski et al. (2015)*	20	RHI	Congruent vs incongruent (arm)
			Congruent vs incongruent (across touch locations)
Limanowski et al. (2016a)	19	RHI	Congruent vs incongruent
Limanowski et al. (2016b)	13	RHI	Real > Fake synch > Fake mixed > Fake asynch
Preston et al. (2016)	32	BSI	Synchronous vs asynchronous across body type
Matsumoto et al. (2020)	28	RFI	Synch after > synch before (across both feet)

Note: 19 fMRI experiments were included in the primary meta-analysis. Bekrater-Bodmann et al. (2014) was not included in the whole-brain meta-analysis. See appendix A for a detailed description of the included peak coordinates from each experiment. RHI; rubber hand illusion, BSI; body-swap illusion, FBI; full-body illusion, EFI; enfacement illusion, RFI; rubber foot illusion.

*= The two contrasts were pooled together.

Activation Likelihood Estimation Meta-Analysis

To synthesize the fMRI literature on the sense of body ownership, the primary meta-analysis (ROI included) was conducted on all the activation foci resulting from the systematic search. To assess the potential impact of the inclusion of results based on ROI analyses, an additional identical whole-brain meta-analysis was conducted, except the foci resulting from ROI analyses were excluded. Foci that survived both whole-brain correction and ROI analysis were included in the whole-brain meta-analysis.

Both meta-analyses were conducted using the coordinate-based meta-analytical method ALE (Eickhoff et al., 2012; Eickhoff et al., 2009; Turkeltaub et al., 2011), as implemented in the GingerALE software version 3.0.2 (Brainmap, n.d.). ALE determines the convergence of activation probabilities between experiments, thereby aiming to refute the null hypothesis that activation foci

of the experiments are uniformly spread throughout the brain. The ALE analyses proceeded through three main steps.

First, ALE-maps were created. In this step, reported activation foci were organized according to each experiment. As all the included experiments were reported in MNI space, no spatial normalization into MNI space was necessary. In ALE, activation foci are treated as the centre of a 3D Gaussian probability distribution (kernel) to account for the spatial uncertainty associated with each focus. The full width at half maximum (FWHM) of this 3D Gaussian kernel, and thus the spatial uncertainty, is determined based on the sample size of the study. The algorithm provides a shorter FWHM, and thereby a tighter distribution, for experiments with larger sample sizes (Eickhoff et al., 2009). This is based on the premise that larger sample sizes should have higher localizing power. This provides every activation focus with a probability of being activated. These calculations were confined to a grey matter mask, due to the increased probability of functional activation within the grey matter (Eickhoff et al., 2009). The GingerALE software provides two options for the grey matter mask to be used, one smaller (more conservative) mask and one larger (dilated 2mm, less conservative) mask. The more conservative mask, which is recommended for fMRI data by the GingerALE manual (Brainmap, n.d.), was used. A voxel-wise map of activation likelihood, for each experiment, was thereby created by taking for each voxel of the created map the maximum probability associated with any one activation focus reported by that experiment (Turkeltaub et al., 2011). This corresponds to the probability of the activation focus with the shortest Euclidean distance to that voxel and ensures that nearby activation foci of a single experiment are not cumulatively influencing the probability values (Turkeltaub et al., 2011). These activation probability maps are called modelled activation maps and each voxel in this map has a probability of the nearest activation foci being present in it. A modelled activation map can be conceptualized as a summary of the results reported in an individual study, taking into account the spatial uncertainty associated with the reported activation foci (Eickhoff et al., 2009). By taking the union of the modelled activation maps, an ALE-map was calculated. The ALE-map consists of voxel-wise ALE scores that describe the convergence of results at each location of the grey matter of the brain (Eickhoff et al., 2009).

The second step of the analysis was to create a p-value map. Here, the ALE scores were compared to an analytically derived null distribution of (null) ALE scores that reflect a random spatial association between experiments (Eickhoff et al., 2012). This enables random-effects inference, which means that the inference is regarding the above-chance convergence between

experiments. The null distribution was derived by converting the modelled activation maps into histograms. These modelled activation histograms thus contain all possible activation probabilities for each experiment, without the spatial information (Eickhoff et al., 2012). The modelled activation histograms were successively integrated into an ALE histogram, thereby deriving the null distribution containing all possible ALE scores under spatial independence (Eickhoff et al., 2012). The p-value of a voxel-wise ALE score, in the real analysis, is then equal to the proportion of equal or higher ALE scores in the null distribution. This results in a voxel-wise map of p-values for ALE scores, which contains each voxel's unthresholded p-value.

The third step was the cluster-level inference. Here, the created p-value map was used to set a significance threshold on the ALE scores. The p-values were initially thresholded using a cluster-forming threshold, which is an uncorrected voxel-wise threshold, to define clusters of interest. The size of the clusters that survived this threshold was then compared to a null distribution of cluster-sizes. The null distribution of cluster-sizes was estimated with Monte Carlo simulation (Eickhoff et al., 2012). With this method, a set of random experiments were simulated, displaying similar properties as the experiments in the real dataset (e.g., number of foci, number of subjects), except that the activation foci were randomly distributed to any voxel within the grey matter mask. The same analysis performed on the real dataset was then performed on the simulated experiments, including the same cluster-forming threshold. The size of the largest cluster above this threshold was stored (Acar, Seurinck, Eickhoff, & Moerkerke, 2018). This simulation was repeated 1000 times, yielding the null distribution. This null distribution of cluster-sizes was then used to identify the cluster-size that was only exceeded in five per cent of the simulations, thereby computing a family-wise error (FWE) corrected cluster-level threshold. The p-values were thresholded using a cluster-forming threshold of $p < .001$ and an FWE corrected cluster-level threshold of $p < .05$, reflecting current recommendations for best practices (Eickhoff et al., 2016; Müller et al., 2018). Clusters large enough to exceed this threshold in the real analysis were considered significant.

Visualization of the resulting activation clusters were overlaid on an MNI template using the Multi-image Analysis GUI (Mango; Mango, n.d.). For labelling, coordinates were transformed into Talairach space using icbm2tal (Lancaster et al., 2007) and results were labelled using Talairach Daemon (Lancaster et al., 2000).

Post-hoc analysis. Compared to traditional meta-analyses, ALE offers few ways to assess the robustness and heterogeneity of the meta-analytic results (Radua & Mataix-Cols, 2012). A recent simulation study has shown that 17 experiments are needed to ensure robust meta-analytical results

(Eickhoff et al., 2016). To study the between-study variance or heterogeneity of studies included in the meta-analysis, subgroup analyses can be conducted (Radua & Mataix-Cols, 2012). However, due to the low number of available experiments, no such subgroup analyses were conducted (Eickhoff et al., 2016).

To provide more detailed information about the significant clusters identified in the primary meta-analysis, it is possible to determine which individual experiments reported activation foci within, and thereby contributed to, each cluster. Examining the contributing experiments could indicate if experiments with specific characteristics are influencing the results. Two specific characteristics were of interest. As we were interested in the effects of ROI analysis on the meta-analytical results, we examined how many of the individual experiments reported results based on ROI analysis. If several of these experiments reported results based on ROI analyses of the regions in the clusters, it would further indicate that the meta-analytical results were driven by ROI experiments. Furthermore, as no subgroup analysis could be conducted, we examined which types of illusions the experiments contributing to each cluster utilized to induce the illusory body ownership. This is a possible source of heterogeneity and could also generate novel hypotheses regarding different neural correlates between ownership for body-parts and the entire body (e.g., Blanke & Metzinger, 2009).

Because this analysis was conducted after inspecting the results of the ALE meta-analyses, it should be considered exploratory.

Results

Systematic Search

Selection and inclusion of studies. The database search yielded a total of 271 articles and the previous meta-analyses yielded an additional 34 articles, for a total of 305 articles. After the removal of duplicates, a total of 158 articles remained and their abstracts were screened. 37 articles were identified as relevant and the full-texts of these articles were further assessed based on the inclusion criteria. See figure 1 for a PRISMA flow chart detailing the screening process.

The literature search yielded a total of 19 fMRI experiments (from 17 articles; table 1), with a total of 369 subjects and 217 activation foci, for inclusion in the primary meta-analysis. For the whole-brain meta-analysis, the exclusion of foci resulting from ROI analyses resulted in one article being excluded (Bekrater-Bodmann et al., 2014). 18 fMRI experiments (from 16 articles), with a total of 344 subjects and 163 activation foci were included in the whole-brain meta-analysis. For a detailed list of the included studies and foci used, see appendix A.

Figure 1

PRISMA Flowchart for Study Inclusion
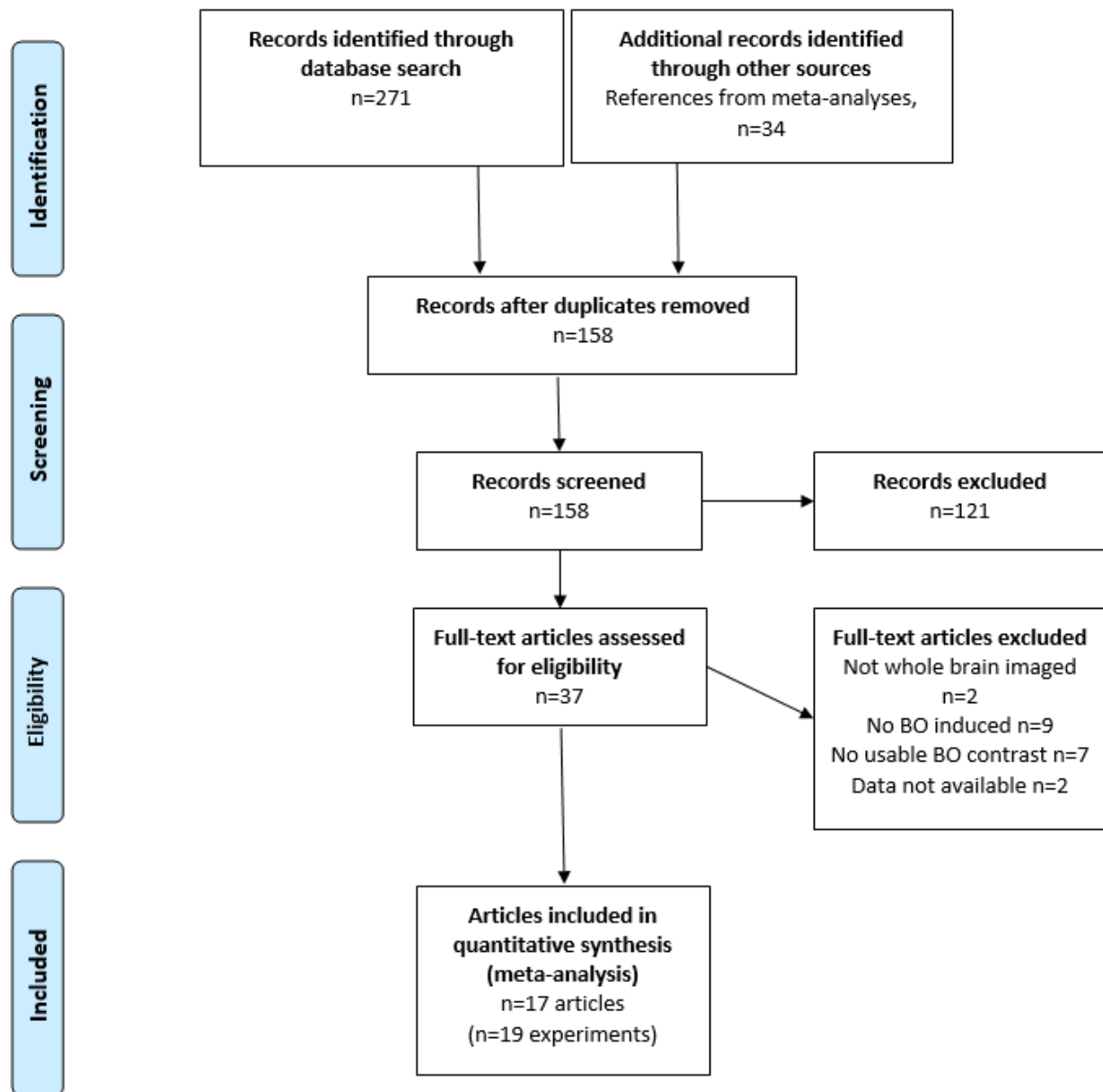
Note. The systematic search yielded a total of 19 experiments for inclusion in the primary meta-analysis.

Characteristics of included studies. 11 of the included experiments investigated the neurofunctional correlates of ownership over a hand, six over a whole body, one over another

person's face, and one over a foot. Different variations of the rubber hand illusion (Botvinick & Cohen, 1998) were used for the experiments investigating ownership over a hand. The whole-body ownership studies used variations of the full-body illusion (Lenggenhager et al., 2007) and the body-swap illusion (Petkova & Ehrsson, 2008). The one study that investigated ownership over another person's face utilized the enfacement illusion (Sforza et al., 2010). Ownership over a foot was studied using the rubber foot illusion (Crea et al., 2015). These illusion conditions were generally compared with a control condition in the form asynchronous stroking (Ehrsson et al., 2004; Guterstam et al., 2015), stroking in an incongruent position (Gentile et al., 2013; Limanowski & Blankenburg, 2015), with the arm detached from the body (Petkova et al., 2011), or to the blood-oxygen-level-dependent (BOLD) response before the induction of the illusion (Matsumoto et al., 2020).

The activation foci resulted from contrasts comparing the factor of interest and a control condition, such as [synchronous stroking condition > asynchronous stroking condition], as well as from interaction effects, such as [synchronous congruent condition > asynchronous congruent condition] versus [synchronous incongruent condition > asynchronous incongruent condition].

Activation Likelihood Estimation Meta-Analysis

Primary meta-analysis. The primary meta-analysis of fMRI studies identified in the systematic search revealed significant convergence of activation in three clusters. Two clusters were located in bilateral posterior parietal areas. The left cluster was mainly located in the inferior parietal lobule, extending to the superior parietal lobule. The right posterior parietal cluster was mainly located in the superior parietal lobule, spanning the precuneus and the inferior parietal lobule. The third cluster was located in the right frontal lobe, primarily in the precentral gyrus, spanning the inferior and middle frontal gyri. Peak activation magnitudes for these clusters were located in the left intraparietal lobule, right superior parietal lobule, and the right precentral gyrus (table 2, figure 2a).

Whole-brain meta-analysis. The separate analysis of only whole-brain results was conducted to assess the impact of ROI analyses on the results of the primary meta-analysis. This analysis identified no significant clusters (figure 2b).

Post-hoc analysis. The examination of the experiments contributing to each of the three significant clusters found in the primary meta-analysis showed that five experiments, from four articles, contributed to the cluster centred in the left inferior parietal lobule (Gentile et al., 2013; Guterstam et al., 2015; Limanowski & Blankenburg, 2015; Petkova et al., 2011). Each of these experiments reported results based on ROI analyses in parietal areas. Two experiments investigated

the neurofunctional correlates of ownership over a hand (rubber hand illusion) and three over an entire body (body-swap illusion).

Table 2

Results of the Primary Meta-Analysis and the Whole-Brain Meta-Analysis.

Cluster	Macroanatomical Label	Cytoarchitectonic Label	x	y	z	ALE score	Volume (mm^3)
	Primary Analysis						
Cluster #1	L Inferior Parietal Lobule	BA 40	-38	-48	56	.020	1024
Cluster #2	R Precentral Gyrus	BA 6	48	8	32	.019	864
Cluster #3	R Superior Parietal Lobule	BA 7	34	-56	54	.017	688
	Whole-Brain Analysis						
	No significant clusters						

Note: Cluster coordinates (weighted centre) are reported in MNI space. Clusters were thresholded at a cluster-forming threshold of $p < .01$ uncorrected, and an FWE corrected cluster-level threshold of $p < .05$. Labelled using Talairach daemon. BA; Brodmann Area.

Four experiments contributed to the cluster centred in the right precentral gyrus (Apps et al., 2015; Ehrsson et al., 2005; Gentile et al., 2013; Petkova et al., 2011). One of these experiments (Apps et al., 2015) reported results based on whole-brain correction, while the other three experiments reported results based on ROI analyses in precentral areas. Two experiments investigated the neurofunctional correlates of ownership over a hand (rubber hand illusion), one over an entire body (body-swap illusion), and one over another person's face (enfacement illusion).

Five experiments contributed to the cluster in the right superior parietal lobule (Apps et al., 2015; Ehrsson et al., 2005; Gentile et al., 2013; Guterstam et al., 2015; Guterstam, Gentile, & Ehrsson, 2013). Once again, only one experiment (Apps et al., 2015) reported results based on whole-brain correction, while the other four reported results based on ROI analyses in parietal areas. Three experiments investigated the neurofunctional correlates of ownership over a hand (rubber

hand illusion), one over an entire body (body-swap illusion), and one over another person's face (enfacement illusion).

Figure 2

Results Meta-Analyses of Body Ownership.
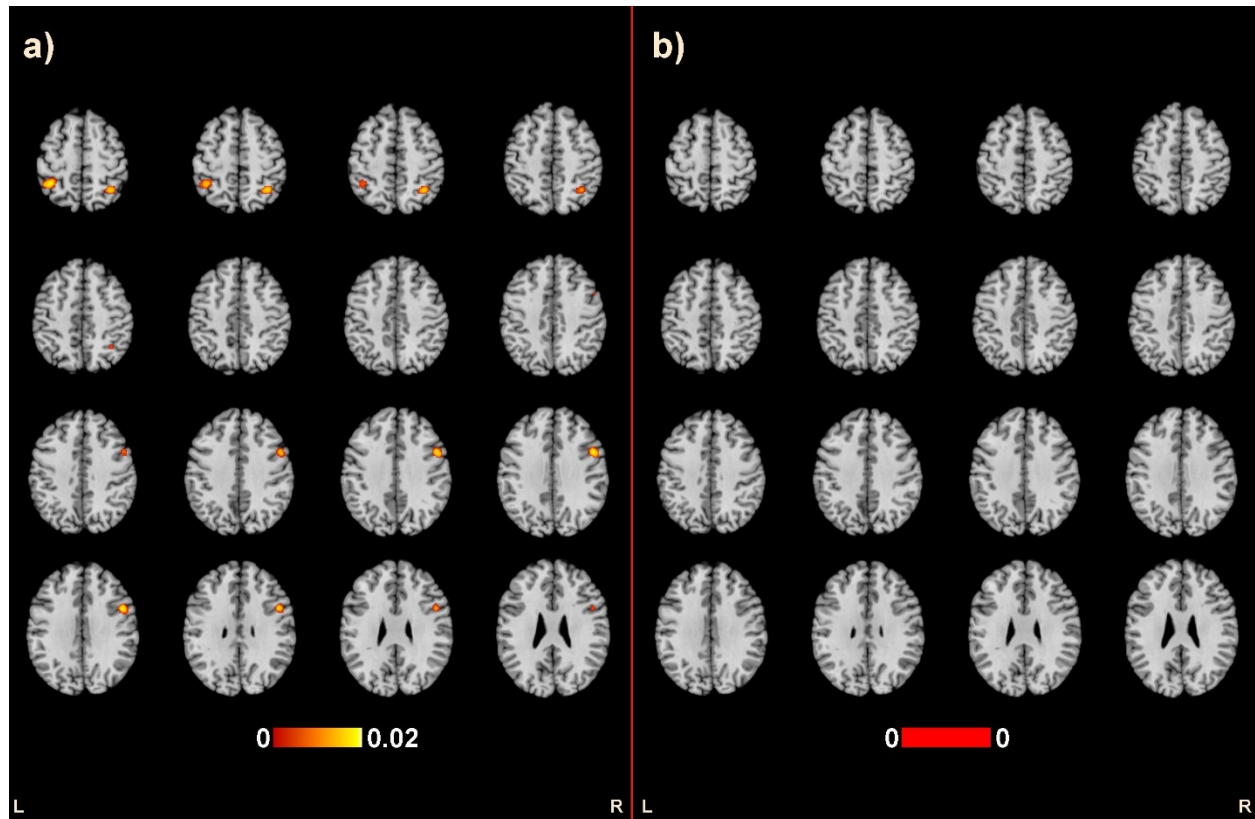
Note. Neurofunctional correlates of body ownership. Results of the ALE meta-analyses were overlaid on an MNI template. Clusters were thresholded at a cluster-forming threshold of $p < .01$ uncorrected, and an FWE corrected cluster-level threshold of $p < .05$. Color intensities correspond to ALE scores, ranging from red (lower) to white (higher). a) The primary meta-analysis (ROI included) showed significant convergence of activation centred in the left intraparietal lobule, right precentral gyrus, and right superior parietal lobule. b) The whole-brain meta-analysis (ROI excluded) showed no significant convergence of activation.

Discussion

Recent attempts to quantitatively synthesize the neuroimaging literature of body ownership have provided conflicting results. In the present thesis, we conducted a quantitative meta-analysis of

the neurofunctional correlates of body ownership, resulting from fMRI experiments of multisensory illusion paradigms. To assess the impact of including experiments based on ROI analyses, a subsequent whole-brain meta-analysis was conducted.

The primary meta-analysis showed consistent convergence of activation in three clusters situated in bilateral posterior parietal regions and right frontal regions. The whole-brain meta-analysis yielded no significant clusters of activation, indicating that the inclusion of activation foci based on ROI analyses influenced the results of the primary meta-analysis.

Neurofunctional Correlates of Body Ownership and Multisensory Integration

The primary meta-analysis identified significant clusters in bilateral posterior parietal regions and right frontal regions, primarily in the precentral gyrus. In non-human primates, multimodal neurons that process visual, tactile, auditory, vestibular and proprioceptive signals have been found in networks of precentral, inferior parietal and intraparietal regions (Graziano, Cooke, & Taylor, 2000; Graziano & Gandhi, 2000; Graziano, Hu, & Gross, 1997). These neurons often have multisensory (e.g., visuo-tactile) receptive fields, which are centred on individual body-parts (Duhamel, Colby, & Goldberg, 1998; Fogassi et al., 1996). Integration in these neurons is optimal when stimuli are temporally synchronous and spatially congruent (Blanke et al., 2015). The spatial and temporal congruence principles exhibited by these frontoparietal neurons are similar to the perceptual rules that determine the induction of the rubber hand illusion (Ehrsson, 2020; see Introduction).

In humans, equivalent precentral and posterior parietal regions are associated with similar multisensory integration mechanisms (Bremmer et al., 2001; Gentile, Petkova, & Ehrsson, 2011; Limanowski & Blankenburg, 2016a; Macaluso & Driver, 2005; Nakashita et al., 2008) and equivalent multimodal neurons have been hypothesized to mediate the sense of body ownership (Ehrsson et al., 2004; Makin, Holmes, & Ehrsson, 2008). Increased effective connectivity between the precentral gyrus and the intraparietal sulcus, correlated with subjective and behavioural measures of ownership, has been observed during the rubber hand illusion (Guterstam et al., 2013).

The posterior parietal cortex has been suggested to encode multisensory spatial representations of individual body parts centred on different reference frames (e.g., hand-centred for the rubber hand illusion), similar to observations in non-human primates (Serino et al., 2013). This process has been hypothesized to start before the onset of the illusion and therefore be a precondition for the subjective experience of body ownership (Makin et al., 2008; Serino et al., 2013).

Activation in the ventral premotor cortex, which is part of the precentral gyrus, has been shown to correlate with the subjective feeling of the rubber hand illusion and the body-swap illusion (Ehrsson et al., 2005; Ehrsson et al., 2004; Gentile et al., 2013; Petkova et al., 2011). It has been hypothesized that the ventral premotor cortex, due to being activated independently of which body-part is stimulated (i.e. hand or abdomen), integrate multisensory information from multiple body parts (Petkova et al., 2011). This multisensory integration mechanism, coupled with the correlation between the ventral premotor cortex and the subjective feeling of full-body ownership, has been hypothesized to result in the sense of body ownership (Makin et al., 2008; Petkova et al., 2011).

From a theoretical standpoint, different views exist on whether or not multisensory integration mechanisms are sufficient to explain the sense of body ownership. The authors of the initial rubber-hand experiment suggested that intermodal matching between vision and touch was sufficient for the sense of ownership over the rubber hand (Botvinick & Cohen, 1998). Since then, several different neurocognitive models have been put forward and have been broadly classified as bottom-up models, which postulate that multisensory integration is sufficient for the sense of body ownership (Ehrsson, 2020; Makin et al., 2008), and top-down models, which suggest that bottom-up multisensory integration is modulated by top-down internal models of the body (Limanowski & Blankenburg, 2013; Tsakiris, 2010). It has been proposed that incoming sensory information (of e.g. a fake hand), processed in frontoparietal multisensory areas, is compared to an internal body model in the right temporoparietal junction (Tsakiris, 2010; Tsakiris, Costantini, & Haggard, 2008). The same model further postulates that the right insula underpins the sense of body ownership (Tsakiris, 2010; Tsakiris, Hesse, Boy, Haggard, & Fink, 2006).

As no significant clusters were found in the temporoparietal junction or the insula, the findings of the primary meta-analysis does not support this model. The convergence of activation found in frontoparietal regions in the primary meta-analysis indicates a bottom-up explanation for body ownership. Ehrsson recently hypothesized that "body ownership can be explained as the formation of a coherent multisensory percept of one's body by multisensory integration mechanisms" (Ehrsson, 2020, p. 194). This parsimonious hypothesis is in line with the findings of our primary meta-analysis.

In the induction of illusory body ownership, multisensory integration is manipulated (i.e. through synchronous vs asynchronous multisensory stimulation), so it is unsurprising that cortical regions that integrate sensory stimuli from the body are commonly hypothesized a priori to be involved. This was the case even for the very first fMRI study of body ownership (Ehrsson et al.,

2004). When results based on ROI analyses were excluded from the meta-analysis, no significant convergence was found anywhere in the brain. We argue that, while the multisensory framework within which body ownership is often studied has been a fruitful one, the frequent use of ROI analysis in multisensory areas has contributed to the difficulty of synthesizing the neuroimaging literature of body ownership. In the following sections, we will propose some future directions for researchers within the field, which will facilitate future meta-analyses of the neurofunctional correlates of body ownership.

The Inclusion of Region of Interest Studies in Meta-Analyses of Body Ownership

An ROI approach has been commonly utilized in individual fMRI studies of body ownership. A qualitative comparison of the results obtained by the primary meta-analysis and the whole-brain meta-analysis shows that important differences in the results can emerge depending on whether or not experiments based on ROI analyses are included. This indicates the importance of correctly handling activation foci from ROI analyses when synthesizing the results of body ownership studies in a meta-analysis. Best practice guidelines for neuroimaging meta-analyses recommend authors to exclude activation foci resulting from ROI analyses, as including them lead to inflated significance for those regions (Müller et al., 2018; Tahmasian et al., 2019). Out of the 19 experiments identified in the systematic search, only five experiments were completely free from any ROI approach (Apps et al., 2015; Guterstam et al., 2013; Ionta et al., 2011; Matsumoto et al., 2020; Preston & Ehrsson, 2016). Furthermore, almost every experiment contributing to the significant clusters in the primary meta-analysis reported results based on ROI analysis. While including ROI results will bias the meta-analytic results toward those regions, excluding a large portion of the literature can instead bias the meta-analytic results away from those regions (Müller et al., 2018). When a large portion of the literature consists of results based on ROI analysis, it becomes difficult to quantitatively synthesize the literature, as following best-practice recommendations and excluding results based on ROI analysis leads to a large amount of findings being excluded.

Using an ROI approach, such as small-volume correction, can be a perfectly valid inferential method (Roiser et al., 2016), assuming a strong a priori hypothesis is justified (Poldrack, 2007). However, the results of these analyses provide a challenge for current coordinate-based meta-analytical methods. A way to facilitate future meta-analyses on body ownership could be for researchers set on using an ROI approach to also report uncorrected whole-brain results, as these can be used in meta-analyses. However, these uncorrected results should not be used for inference in the individual studies (Roiser et al., 2016). Furthermore, online repositories such as *OpenfMRI*

(Poldrack et al., 2013) and *NeuroVault* (Gorgolewski et al., 2015) can be used to upload unthresholded statistical maps. This would facilitate image-based meta-analyses, which do not have to rely on coordinates of statistical significance (Salimi-Khorshidi, Smith, Keltner, Wager, & Nichols, 2009). Databases for coordinate data, such as *Neurosynth* (Yarkoni, Poldrack, Nichols, Van Essen, & Wager, 2011), can further be used for automated collection of data for neuroimaging meta-analyses and could in the future offer the possibility of conducting fully automated meta-analyses. This could potentially limit the impact that the subjective choice of inclusion criteria can have on the meta-analytic results.

Whole-Brain Meta-Analysis and Heterogeneity

An important point to make regarding the results of the whole-brain meta-analysis is that ALE, unlike classical effect-size meta-analyses in clinical and behavioural sciences, do not focus on the presence or absence, nor the strength, of an effect at any given location. ALE rather identify the spatial convergence across data, which means that the null findings of the whole-brain meta-analysis does not indicate the lack of an effect in body ownership experiments, rather the lack of convergent findings across experiments. This lack of convergence indicates high levels of heterogeneity. The experiments included used different types of illusions (e.g., rubber hand illusion and body-swap illusion), sensory modalities, and were conducted on different body parts (e.g., hand and abdomen). Furthermore, different laboratories use different experimental set-ups, methods for induction, measures of the effect, and experimental designs, which influence the behavioural measures of body ownership (Riemer, Trojan, Beauchamp, & Fuchs, 2019). This heterogeneity likely influenced the meta-analytic results. Due to the low number of included studies, no subgroup analyses between different types of illusions or body-parts were conducted. Importantly, heterogeneity within an ALE meta-analysis could indicate the existence of functional sub-domains (Ngo et al., 2019).

A distinction has been made regarding partial ownership, such as limb-ownership studied in the rubber hand illusion, and global ownership, such as in full-body illusions (Blanke & Metzinger, 2009). It has been argued that global ownership, often called self-identification, can only be studied using full-body illusions (Blanke & Metzinger, 2009). The qualitative analysis of the experiments contributing to the significant clusters in the primary meta-analysis showed no clear difference between the types of illusions contributing to the different clusters. Similar multisensory processes have been proposed to underlie full-body ownership and limb-ownership (Ehrsson, 2020; Petkova et al., 2011). While premotor and posterior parietal regions have been implicated in both limb-ownership and self-identification (Petkova et al., 2011), multivoxel pattern analysis has indicated a

more fine-grained distinction between these brain regions (Gentile et al., 2015). Ventral premotor neurons have been shown to integrate multisensory information from several body-parts (hand, leg, and trunk), while other brain regions, including posterior parietal regions, were shown to integrate multisensory information from individual body-parts (Gentile et al., 2015). Including limb-ownership experiments and full-body ownership experiments in the same meta-analysis, under the assumption that they study the same phenomenon, may thus be questionable.

In any meta-analysis, there is a trade-off between the number of experiments included and the amount of heterogeneity (Müller et al., 2018). Currently, not enough experiments exist to conduct separate meta-analyses of, for example, the neurofunctional correlates of ownership over a hand and the entire body. The conducted literature search, which included experiments reporting results based on ROI analysis, identified 11 experiments investigating the neurofunctional correlates of ownership over a hand and six over an entire body. Investigating heterogeneity across a small number of experiments is of questionable value (Deeks, Higgins, & Altman, 2019). To achieve sufficient statistical power, as well as to minimize the risk that results are largely driven by a single experiment, 17-20 included experiments are recommended as a lower limit in an ALE meta-analysis (Eickhoff et al., 2016; Müller et al., 2018). Furthermore, reliable conclusions about heterogeneity can only be drawn from pre-specified analyses and not analyses conducted after inspecting the meta-analytic results (Deeks et al., 2019). Although this question is of great theoretical and practical importance, due to the low number of included experiments, no subgroup analyses were conducted in the present meta-analysis. With more experiments, subgroup analyses of, for example, limb-ownership and self-identification, would become a possibility. These subgroup results could then be subjected to a second-level contrast analysis, providing a quantitative analysis of the neurofunctional similarities and differences between limb-ownership and self-identification. Importantly, analyses across more homogenous experiments can provide information about which type of heterogeneity the lack of convergence in the whole-brain meta-analysis is due to.

To facilitate future meta-analytical investigations into the possible sources of heterogeneity in the body ownership literature, including the possible existence of functional sub-domains, more experiments of limb-ownership (e.g., rubber hand illusion) and self-identification (e.g., body-swap illusion) are needed. We suggest an increased effort toward analyzing these future experiments using a more data-driven, whole-brain approach. This is due to the aforementioned problems of including ROI-based findings in meta-analyses (Müller et al., 2018). Replication studies with larger sample sizes will provide researchers with the statistical power necessary to test their hypotheses using a

whole-brain approach (Cremers et al., 2017). A future whole-brain meta-analysis offers the potential to provide robust conclusions about which brain areas are involved in body ownership, including subgroup analyses investigating potential neurofunctional differences between self-identification and limb-ownership, as well as other sources of heterogeneity. These meta-analytical results, rather than individual studies, can furthermore be used to derive ROIs, which will be less sensitive to noise and ensure strong a priori hypotheses in individual fMRI experiments (Poldrack, 2007).

Finally, data sharing, reproducibility, and replication have gained increased attention within the field of neuroimaging in recent years (Hong, Yoo, Han, Wager, & Woo, 2019; Szucs & Ioannidis, 2017; Wager et al., 2009). We view this as a positive direction and hope that our findings will contribute to the awareness of the importance of, as well as the possible insights to be gained with, these practices within the field of body ownership.

Limitations

Several limitations should be noted. First, the number of experiments included in the primary meta-analysis (19: 369 subjects) and the whole-brain meta-analysis (18: 344 subjects) is relatively modest. The present results would, therefore, benefit from future confirmation that relies on more extensive datasets.

Second, the many different experimental paradigms and set-ups contribute to heterogeneity and may affect the validity of the results. As previously mentioned, no subgroup analysis was conducted, due to the low number of experiments.

Furthermore, only one of the rubber hand experiments used both left and right arms (Limanowski & Blankenburg, 2016b), while each other rubber hand experiment used the right arm. As these studies used tactile stimulation, which has been shown to activate contralateral brain regions (Eickhoff, Grefkes, Fink, & Zilles, 2008), this could constitute a bias toward finding results in the left hemisphere.

Finally, because the present meta-analyses relied on peak coordinates from published results, publication bias, the increased likelihood of studies with statistically significant results being published, may have limited our findings (Ioannidis, Munafò, Fusar-Poli, Nosek, & David, 2014).

Conclusions

The present meta-analyses indicate inconsistencies across the results of fMRI studies of body ownership. When results from individual experiments based on ROI analysis are included in the meta-analysis, frontoparietal multisensory areas are involved in the sense of body ownership. However, a second, whole-brain meta-analysis, without ROI based results, showed no significant

convergence across experiments. These findings highlight the difficulty of quantitatively synthesizing a literature where a large proportion of findings are based on ROI analysis. We recommend more studies, data sharing, and replication studies with large sample sizes to better facilitate future syntheses of the neuroimaging literature of body ownership, including the investigation of potential sources of heterogeneity.

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Appendix A

Coordinates and Thresholding Method for Studies Included in the Primary Meta-Analysis.

Author and Year	Statistical Contrast	Stereotaxic Space	x	y	z	Threshold*
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−48	6	20	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	48	6	20	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−50	−6	50	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	52	10	42	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−20	4	52	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	8	12	62	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−32	22	8	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	32	24	4	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−30	−60	56	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	38	−54	54	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	52	−30	46	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−44	−64	−10	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	56	−54	−8	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	42	−80	24	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−18	−26	6	Whole-brain

Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−26	−60	−28	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	−24	−70	−44	Whole-brain
Guterstam et al (2013)	Synchronous vs asynchronous inclusively masked with the synchronous versus incongruent condition	MNI	32	−70	−28	Whole-brain
Preston et al (2016)	Synchronous vs asynchronous across body type	MNI	28	−66	45	Whole-brain
Preston et al (2016)	Synchronous vs asynchronous across body type	MNI	−20	−63	37	Whole-brain
Preston et al (2016)	Synchronous vs asynchronous across body type	MNI	30	−67	−32	Uncorrected
Preston et al (2016)	Synchronous vs asynchronous across body type	MNI	45	−58	−6	Whole-brain
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−38	−48	54	ROI
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−60	−34	48	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	34	−46	42	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−60	−6	38	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−30	18	10	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−34	−6	12	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−60	12	28	ROI
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	54	4	34	ROI
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−44	42	24	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	52	40	12	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	56	16	28	Uncorrected
Petkova et al (2011)	Syn > Asy - Human >Wood	MNI	−22	−8	8	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−46	−48	56	ROI
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	44	−28	38	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−44	−22	34	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	46	−14	30	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−2	−46	10	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	62	2	26	ROI
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−54	20	34	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−4	−22	44	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−2	−14	44	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	6	46	18	Uncorrected

Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−20	18	54	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−18	26	36	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−30	10	50	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	32	10	48	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	32	32	26	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−38	34	26	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−12	42	26	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	8	38	42	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	6	58	−6	Uncorrected
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	−26	−8	6	ROI
Petkova et al (2011)	Syn > Asy - first person > third person)	MNI	24	−8	8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−8	−76	24	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−4	−56	8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	16	−64	16	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−16	−62	6	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	14	−38	−6	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−12	−44	2	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	20	−100	4	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	24	−98	−4	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−20	−100	−8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	42	−78	28	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	30	−34	68	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	54	−28	52	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	14	−36	74	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−24	−26	74	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−40	−36	62	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−42	−38	46	ROI
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	58	−44	26	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	64	−20	44	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−68	−34	26	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−42	−48	34	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	40	−32	20	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	10	−62	48	Uncorrected

Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	40	−14	−8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−46	6	0	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	54	−18	6	Whole-brain
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−44	−18	−2	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	48	−48	−8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−54	−58	−10	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	26	−30	−20	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−50	−76	22	Whole-brain
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	36	−12	66	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−30	−12	56	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−48	6	32	ROI
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−38	−6	32	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	8	−12	72	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−2	−8	58	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	16	50	−8	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	26	6	56	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−24	−6	62	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−22	60	10	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	38	58	2	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−30	26	36	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	2	−10	30	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−2	12	28	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−12	−24	42	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−6	−2	36	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	20	32	−14	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	28	−48	−30	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−26	−40	−28	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−14	−86	−38	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	28	18	−6	Uncorrected
Petkova et al (2011)	Syn > Asy - Attached hand > Detached	MNI	−26	4	−8	Uncorrected
Limanowski et al (2014)	Congruent vs incongruent spatial stimulation for RHI vs control object	MNI	−42	−68	8	ROI
Limanowski et al (2014)	Congruent vs incongruent spatial stimulation for RHI vs control object	MNI	−40	16	10	ROI

Limanowski et al (2014)	Congruent vs incongruent spatial stimulation for RHI vs control object	MNI	48	8	10	Uncorrected
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	−40	−70	−2	Both
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	24	−64	−36	Whole-brain
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	−20	18	40	Whole-brain
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	−38	10	28	Both
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	−42	−50	58	ROI
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	−34	18	−2	Uncorrected
Limanowski et al (2015)	congruent vs incongruent (across touch locations)	MNI	32	22	−2	Uncorrected
Limanowski et al (2015)	congruent vs incongruent (arm)	MNI	−40	−60	−2	Whole-brain
Limanowski et al (2015)	congruent vs incongruent (arm)	MNI	−2	−60	−34	Whole-brain
Limanowski et al (2015)	congruent vs incongruent (arm)	MNI	−40	12	28	Whole-brain
Ionta et al (2011)	Body-by-stroking interaction	MNI	−54	−32	20	Whole-brain
Guterstam et al (2015)	sync vs async across positions	MNI	−58	8	34	ROI
Guterstam et al (2015)	sync vs async across positions	MNI	−22	2	60	ROI
Guterstam et al (2015)	sync vs async across positions	MNI	−34	−46	58	ROI
Guterstam et al (2015)	sync vs async across positions	MNI	−22	−56	54	Uncorrected
Guterstam et al (2015)	sync vs async across positions	MNI	32	−54	54	ROI
Guterstam et al (2015)	sync vs async across positions	MNI	−42	−74	−8	Uncorrected
Guterstam et al (2015)	sync vs async across positions	MNI	48	−66	−12	Uncorrected
Guterstam et al (2015)	sync vs async across positions	MNI	18	−28	6	Uncorrected
Gentile et al (2015)	average decoding maps for synch vs async	MNI	−30	−10	58	ROI
Gentile et al (2015)	average decoding maps for synch vs async	MNI	50	−36	54	ROI
Gentile et al (2015)	average decoding maps for synch vs async	MNI	−48	−66	2	ROI
Gentile et al (2015)	average decoding maps for synch vs async	MNI	−28	−16	−6	ROI
Gentile et al (2015)	average decoding maps for synch vs async	MNI	−66	−18	36	Uncorrected
Gentile et al (2015)	average decoding maps for synch vs async	MNI	34	−66	34	Uncorrected
Gentile et al (2015)	average decoding maps for synch vs async	MNI	12	−76	60	Uncorrected

Gentile et al (2015)	average decoding maps for synch vs async	MNI	36	−88	−34	Uncorrected
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−36	−44	58	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−42	−40	50	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−30	−50	64	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	38	−42	56	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	36	−56	48	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−48	4	26	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	48	6	36	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	38	−4	58	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−56	−32	36	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	44	−38	36	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	56	−58	−4	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	60	−22	32	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	24	−66	−46	ROI
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	−30	−4	46	Uncorrected
Gentile et al (2013)	(Congr Match - TimeIncong Match) - (Congr Mismatch - TimeIncong Mismatch)	MNI	48	−28	22	Uncorrected
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−54	12	3	ROI

Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−60	9	9	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	45	−6	57	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	48	9	30	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−39	−57	51	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−33	−72	−24	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−15	−81	−27	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	−6	−81	−30	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	36	−75	−24	ROI
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	57	18	3	Uncorrected
Ehrsson et al (2005)	(illusion - asynchronous) + (illusion - incongruent)	MNI	36	−57	60	Uncorrected
Ehrsson et al (2004)	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)	MNI	−48	24	−12	Uncorrected
Ehrsson et al (2004)	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)	MNI	48	18	39	ROI
Ehrsson et al (2004)	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)	MNI	54	18	−12	Uncorrected
Ehrsson et al (2004)	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)	MNI	0	−33	33	Uncorrected
Ehrsson et al (2004)	(Sync Cong - Async Cong) - (Sync Incong - Asyn Incong)	MNI	−57	15	9	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	56	−30	50	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	−50	4	36	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	50	−4	38	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	−20	6	0	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	20	12	−8	ROI
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	48	−10	24	Uncorrected
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	−28	−74	50	Uncorrected
Brozzoli et al (2012)	(Synch first - Synch second) - (Asynch first - Asynch second)	MNI	−60	−28	34	Uncorrected
Bekrater-Bodmann et al (2014)	sync vs async	MNI	56	−6	50	ROI

Bekrater-Bodmann et al (2014)	sync vs async	MNI	−26	−56	64	ROI
Apps et al (2015)	congruency x synch interaction	MNI	−14	−64	−2	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	30	−96	−8	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	−22	−96	0	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	36	24	14	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	−36	16	8	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	38	−12	10	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	58	−44	18	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	−24	−62	54	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	66	−10	18	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	48	8	30	Whole-brain
Apps et al (2015)	congruency x synch interaction	MNI	28	−58	52	Both
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−18	32	−18	Whole-brain
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	14	34	−14	Whole-brain
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	20	−50	−26	Whole-brain
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	30	−32	−16	Whole-brain
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−20	−40	−24	Whole-brain
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−50	−74	−4	ROI
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	56	−64	−6	ROI
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−40	−80	−14	Uncorrected
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−20	32	42	Uncorrected
Limanowski et al (2016b)	Real > Fake synch > Fake mixed > Fake asynch	MNI	−26	14	50	Uncorrected
Limanowski et al (2016a)	Congruent vs incongruent	MNI	−58	−24	30	Whole-brain
Limanowski et al (2016a)	Congruent vs incongruent	MNI	−10	−52	60	Whole-brain
Limanowski et al (2016a)	Congruent vs incongruent	MNI	−14	−68	46	Whole-brain
Limanowski et al (2016a)	Congruent vs incongruent	MNI	−50	−72	4	Whole-brain
Limanowski et al (2016a)	Congruent vs incongruent	MNI	−56	12	22	ROI

Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	14	42	4	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	−2	32	26	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	34	44	34	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	−28	36	24	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	52	−44	20	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	−48	−58	10	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	4	−64	10	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	0	−90	0	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	20	−48	−20	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	−30	−74	−30	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	2	−56	−22	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	2	−10	4	Whole-brain
Matsumoto et al (2020)	Synch after > synch before (across both feet)	MNI	−8	−10	14	Whole-brain

Note: The two different contrasts in Limanowski et al. (2015) were pooled into a single contrast (Turkeltaub et al., 2011). Coordinates that were significant after correction for the whole-brain and the ROI (both) were included in the whole-brain meta-analysis.

*= Uncorrected peaks were all thresholded at p < .001 (uncorrected).