Atlas-informed computational processing pipeline for individual targeting of brain areas for therapeutic navigated transcranial magnetic stimulation

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Highlights

- Anatomical identification of cortical target areas for navigated TMS is challenging.
- Fitting the Brainnetome Atlas to the individual brain enabled consistent targeting.
- Overlaying atlas information in the navigation view is a useful add-on for improving TMS targeting.

Abstract

Objective: Navigated transcranial magnetic stimulation (nTMS) is targeted at different cortical sites for diagnostic, therapeutic, and neuroscientific purposes. Correct identification of the cortical target areas is important for achieving desired effects, but it is challenging when no direct responses arise upon target area stimulation. We aimed at utilizing atlas-based marking of cortical areas for nTMS targeting to present a convenient, rater-independent method for overlaying the individual target sites with brain anatomy.

Methods: We developed a pipeline, which fits a brain atlas to the individual brain and enables visualization of the target areas during the nTMS session. We applied the pipeline to our previous nTMS data, focusing on depression and schizophrenia patients. Furthermore, we included examples of Tourette syndrome and tinnitus therapies, as well as neurosurgical and motor mappings.

Results: In depression and schizophrenia patients, the visually selected dorsolateral prefrontal cortex (DLPFC) targets were close to the border between atlas areas A9/46 and A8. In the other areas, the atlas-based areas were in agreement with the treatment targets.

Conclusions: The atlas-based target areas agreed well with the cortical targets selected by experts during the treatments.

Significance: Overlaying atlas information over the navigation view is a convenient and useful add-on for improving nTMS targeting.

1. Introduction

Transcranial magnetic stimulation (TMS) is used in repetitive TMS (rTMS) and theta-burst stimulation (TBS) modes for neuro-modulation therapy in a variety of conditions. Based on strong evidence from meta-analyses, European guidelines recommend applying high-frequency rTMS for beneficial effects on neuropathic pain and major depression (Lefaucheur et al. 2014, 2020). For these indications, the primary motor cortex (M1) contralateral to pain side and the left dorsolateral prefrontal cortex

Abbreviations: BA, Brodmann area; DLPFC, dorsolateral prefrontal cortex; DTI, diffusion tensor imaging; EEG, electroencephalogram; FDI, first dorsal interosseous; fMRI, functional magnetic resonance imaging; MRI, magnetic resonance imaging; M1, primary motor cortex; nTMS, navigated transcranial magnetic stimulation; OCD, obsessive compulsive disorder; OFC, orbitofrontal cortex; rsfMRI, resting state functional magnetic resonance imaging; rTMS, repetitive transcranial magnetic stimulation; SMA, supplementary motor area; S2, secondary somatosensory cortex; TBS, theta-burst stimulation.

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(DLPFC) should be targeted, respectively (O’Reardon et al. 2007; George et al. 2010; Hosomi et al. 2013). The updated guidelines also recommend applying low-frequency rTMS of contralesional M1 at the post-acute stage after stroke (Lefaucheur et al. 2020). In addition, the guidelines suggest probable efficacy for the use of low-frequency rTMS of the right DLPFC in depression and high-frequency rTMS of ipsilesional M1 at the post-acute stage after stroke (Lefaucheur et al. 2014, 2020). Additional treatment targets with possible positive effects include the left auditory cortex in tinnitus and the supplementary motor area (SMA) in obsessive compulsive disorder (OCD) (Lefaucheur et al. 2014; Singh et al. 2019).

Treatment target localization is crucial for treatment outcome; therefore, utilization of neuronavigation in TMS therapy has been proven to provide more appropriate and successful targeting than non-navigated approaches (Lefaucheur et al. 2007; Fitzgerald et al. 2009b; Herbsman et al. 2009; Ahdab et al. 2010). When targeting therapy to motor areas, navigated TMS (nTMS) mapping can be utilized for treatment target selection (Vitikainen et al. 2009; Julkunen 2014). In non-motor areas, such as the DLPFC, targets based on external landmarks have mainly been used when neuronavigation is not available (Lefaucheur et al. 2014). This “standard” approach locates the DLPFC target 5 cm anteriorly to the M1 (George et al. 1995), often failing to reach the correct cortical region (Herwig et al. 2001). Other proposed methods for more accurate DLPFC targeting include electroencephalogram (EEG) electrode positions F3 and F5 (for left DLPFC) (Rusjan et al. 2010), visual estimation based on structural magnetic resonance images (MRIs) using anatomical landmarks (Mylius et al. 2013) or indirect clearly identifiable anatomical features (Pommier et al. 2017), and connectivity-based target selection (Fox et al. 2012a, 2013). The use of external or anatomical landmarks for setting the treatment target tends to cause variability in target selection (Ahdab et al. 2010), which also increases the between-study variability in the reported therapeutic effects of TMS. Therefore, a clear, individualized method independent from rater-specific interpretation would be preferable.

Treatments for various conditions have widely extended the applicability of nTMS. However, treatment target identification is often done by clinicians who are not necessarily accustomed with MRI in their clinical work. The typical anatomical treatment targets are in the DLPFC, M1, or the auditory cortex, which are often referred to with their specific associated Brodmann areas (BAs). Conventional DLPFC targets are located at the mediodiastal part of BA46, lateral to BA9 and anterior to BA8 (Fitzgerald et al. 2009b; Fox et al. 2012a), M1 is located in BA44, and the auditory cortex is approximately in BA41 and BA42. Optional targets for pain therapy are in the right secondary somatosensory cortex (S2) (Lindholm et al. 2015). For OCD, targets are in SMA and the orbitofrontal cortex (OFC) (Singh et al. 2019).

The Brodmann atlas contains invaluable information on structural–functional relationships based on cortical cytoarchitecture (Amunts and Zilles 2015). However, this classical cortical map was constructed by analyzing a single hemisphere, neglecting the inter-individual variability. It does not provide accurate information on the borders of the cortical areas. Furthermore, it represents only local features, ignoring the long-range connections of the brain, which are crucial in determining the functions of a cortical area (Passingham et al. 2002). Incorporating these connections into brain mapping reveals a more heterogeneous cortical architecture, providing refined atlases with fine-grained parcellations. The Brainnetome Atlas (Fan et al. 2016), which we utilize, has been constructed by parcellating the cortical anatomy based on structural connectivity information from 40 brains. It uses the BAs in nomenclature, since most clinicians and researchers are familiar with this labeling approach (Fig. 1).

The aim of the present study is to provide a demonstration of a pipeline, which utilizes the Brainnetome Atlas (Fan et al. 2016) with FreeSurfer (Fischl 2012) to enable identification of crucial target areas over structural MRI volumes of the patients. This allows target selection during the TMS treatment session by utilizing individually fitted atlas information. We note that the applied atlas provides areas based on anatomical connectivity; therefore, the resulting areas differ from the conventional BAs. We demonstrate the pipeline retrospectively in various rTMS therapy patients and healthy subjects, focusing primarily on the DLPFC. The pipeline presented in this study will provide an approach to more efficient and stable treatment target selection for rTMS and TBS therapies.

2. Methods

2.1. Subjects and imaging

We analyzed 22 subjects (mean age: 35.5 years, range: 17–67 years, 13 male, 9 female). A summary of the subjects and treatment target areas is presented in Table 1. Prior to nTMS, structural three-dimensional T1-weighted MRI volumes were acquired with a 3-T scanner (Philips Achieva 3.0TX, Philips, Eindhoven, The Netherlands). Two different commercial nTMS systems were used: eXimia 3.2 and NBS 4.2 (Nexstim Plc, Helsinki, Finland).

2.2. Pipeline

The applied pipeline used a three-dimensional, T1-weighted MRI and some user-defined parameters as inputs and automatically performed multiple processing steps to produce a final cortical volume that can be overlaid with the original MRI in the nTMS system (Fig. 2). The processing steps utilized several functions of the FreeSurfer suite (Fischl 2012), together with the connectivity-based parcellation data provided by the Brainnetome Atlas (Fan et al. 2016).

First, the MRI DICOM image stack was converted into a volume file (NIfIT format). This volume was segmented and parcellated with FreeSurfer reconstruction methods to obtain a gyral-based cortical parcellation (Desikan et al. 2006). This initial parcellation was divided into sub-regions by the Brainnetome Atlas, which was mapped to the processed image. After this step, a registration matrix was created, which performed a mapping from the atlas space (the standard MNI space) to the individual MRI coordinates. By utilizing the atlas, the regions of interest were identified based on atlas label indices representing the parcellated sub-regions. Finally, the selected labels (see Appendix A for the specific atlas indices) were converted into an image volume, where the volume between the white matter surface and pia mater was painted (Fig. 3). By utilizing the previously formed registration matrix, the final image volume was transformed into the individual MRI space, which enabled visualizing the target area on individual cortical anatomy in the nTMS session.

The pipeline was implemented in a single Linux shell script (Appendix C). We used FreeSurfer version 6.0.0 in Ubuntu 16.04, installed in VirtualBox version 5.2.8 (Oracle Co, San Francisco, CA) under Windows 7 and 10 (Microsoft Co, Redmond, WA) operating systems. The time required for running the pipeline was about 12 h.

2.3. Comparison with alternative approaches

The pipeline was applied retrospectively to all subjects. In the DLPFC, the neuroanatomical method proposed by Mylius et al. (2013) was applied to obtain a reference target, and the shortest
distance of this target to the edges of the neighboring atlas-based areas (A9/46, A8, and A9) was calculated. Thus, the reference target in the DLPFC did not represent the actual treatment target applied for the depression and schizophrenia patients. We aimed at comparing the applicability of the neuroanatomical reference method and the atlas pipeline in these patients, since both of these conditions may alter the cortical neuroanatomy (Schmaal et al. 2017; van Erp et al. 2018).

In the other cortical treatment areas (SMA and auditory cortex), we validated the pipeline visually by overlaying the treatment target selected by the clinician during the treatment session with the atlas-based target area produced by the pipeline. The neurosurgical language mappings (stimulation sites associated with responses) were also overlaid with the atlas-based Wernicke’s area. In these mappings, the patients performed object-naming tasks, and rTMS was used to impair task performance (Krieg et al. 2017). The coil was moved randomly over the perisylvian cortex with the orientation approximately perpendicular to the nearest sulcus.

Finally, the agreement between the mapped motor cortical target, and the target area provided by the pipeline was also visualized in case fashion. The reference target in the motor cortex was the hotspot of the first dorsal interosseous (FDI) muscle, which was located accurately in an nTMS motor mapping protocol. This protocol applied a slightly suprathreshold stimulation inducing around 1-mV motor-evoked potentials (MEPs) in the target muscle. The stimulation was started from the anatomically identified “hand knob” (Yousry et al. 1997) and extended to the neighboring sites until no MEPs were elicited. The stimulation site repeatedly producing the highest MEPs was identified as the FDI hotspot.

### 3. Results

The applied pipeline functioned fully in all subjects. In the depression (S1–S10, Fig. 4) and schizophrenia (S11–S13, Fig. 4) patients, the visually determined DLPFC targets were located in the atlas area A9/46 (62% of the targets) or in A8 (38% of the targets). Table 2 shows the shortest distances of these targets to the edges of the neighboring areas A9/46, A8, and A9, separately for both hemispheres. For the targets in A8, the distance to A9/46 was 7 ± 3 mm (both hemispheres). For the targets in A9/46, the distance to A8 was 5 ± 3 mm. For all the DLPFC targets, the distance to A9 was 21 ± 5 mm. The targets were thus located close to the border between A9/46 and A8, lateral to A9 (Fig. 4).

In the Tourette syndrome patients (S14–S15, Fig. B1 in Appendix B), the applied therapy targets were located in the target area (SMA) produced by the pipeline. In the tinnitus patient (S16, Fig. B1 in Appendix B), the therapy target was located in the atlas-based auditory cortex. In the neurosurgical mapping patients (S17–S18, Fig. B2 in Appendix B), most of the stimulation sites associated with responses were in agreement with the obtained target areas. Based on qualitative, visual estimation, these target areas (auditory cortex and Wernicke’s area) were consistent with their common neuroanatomical locations. The motor cortex was also effectively visualized by the pipeline for the motor mapping subjects (S19–S22, Fig. B3 in Appendix B). This target area corresponded well with the hotspot of the FDI muscle (Fig. B3 in Appendix B): all hotspots were located in the target area.

### Table 1

Summary of subjects and nTMS target areas. DLPFC, dorsolateral prefrontal cortex; M1, primary motor cortex; rTMS, repetitive transcranial magnetic stimulation; SMA, supplementary motor area.

| Indication/purpose | System   | Target                   | Number of subjects | Reference method                      |
|--------------------|----------|--------------------------|--------------------|---------------------------------------|
| Depression, rTMS therapy | NBS 4.2  | DLPFC                    | 10                 | Mylius et al. (2013)                   |
| Schizophrenia, rTMS therapy | eXimia 3.2 | DLPFC                    | 3                  | Mylius et al. (2013)                   |
| Tourette, rTMS therapy       | eXimia 3.2 | SMA                     | 2                  | Treatment target selected by a clinician |
| Tinnitus, rTMS therapy       | eXimia 3.2 | Auditory cortex          | 1                  | Treatment target selected by a clinician |
| Neurosurgical mapping        | NBS 4.2  | Wernicke’s area          | 2                  | Language mapping                      |
| Research, motor mapping      | NBS 4.2  | M1                      | 4                  | Motor mapping                         |

**Fig. 1.** Various target areas identified in a single subject on both hemispheres based on the Brainnetome Atlas (Fan et al. 2016). M1, primary motor cortex; SMA, supplementary motor area; S2, secondary somatosensory cortex.
In the current study, we demonstrated how a brain atlas can be applied for identifying individualized treatment target areas for rTMS and TBS therapies. The resulting target areas agreed well with the reference targets in the DLPFC, SMA, auditory cortex, Wernicke’s area, and M1.

In the DLPFC, the targets determined with the neuroanatomical method (Mylius et al. 2013) were located in A9/46 or A8 of the Brainnetome Atlas (Fan et al. 2016), close to the border between these two areas and lateral to A9 (Fig. 4). The original method (Mylius et al. 2013) targets the junction between anatomical areas BA9 and BA46 in the Talairach atlas, which has different area definitions than the Brainnetome Atlas; this junction is likely a part of A9/46 in the Brainnetome Atlas as implied by the best agreement with the method of Mylius et al. (2013) (Table 2). This conventional method uses the precentral sulcus and the olfactory sulcus as anatomical landmarks for specifying the target location in the posterior–anterior axis, which may cause variability in this direction (Pommier et al. 2017). For locating the target in the medial–lateral direction, the neuroanatomical method requires identifying the middle frontal gyrus. In the Brainnetome Atlas, the middle frontal gyrus near the neuroanatomical target corresponds to areas A9/46 and A8vl (Fan et al. 2016). By using the proposed pipeline, locating the center of the border between A9/46 and A8vl potentially provides an individual, rater-independent method for targeting the DLPFC. This approach targets the DLPFC in a more consistent manner and is less prone to human errors than the conventional method based on anatomical landmarks.

The DLPFC is a relatively large area, which is often assumed to consist of the conventional areas BA46, BA9, and area A9/46 introduced by Petrides and Pandya (1999). There is no consensus on the most effective target area in context of medication-resistant depression; previous studies have suggested targeting BA46 (Fox et al. 2012a), BA9 (Luber et al. 2017), and also their junction (Fitzgerald et al. 2009a; Herbsman et al. 2009) to enhance the therapeutic effects. Conventionally, these areas are derived from the Talairach atlas, which can lead to erroneous designations due to high inter-individual anatomical variability that still remains after transformation to a reference brain (Uylings et al. 2005). The accurate specification of individual BAs requires microstructural analysis of the post-mortem brain; however, probabilistic brain atlases enable macrostructural estimation based on in vivo MRI. Alternative connectivity-based methods apply individual resting state functional MRI (rsfMRI) (Fox et al. 2012b; Cole et al. 2020).

The Brainnetome Atlas provides a fine-grained, connectivity-based parcellation, which enables targeting based on anatomical

![Fig. 2](image2.png)

**Fig. 2.** Pipeline and the steps of image processing, all (black boxes) implemented in a script for running in series. MRI, magnetic resonance image; nTMS, navigated transcranial magnetic stimulation.

![Fig. 3](image3.png)

**Fig. 3.** Automatically painted cortical volume representing the Brainnetome Atlas area A9/46 (blue area) between white matter surface (yellow) and pia mater (red) on the left hemisphere.
and functional connectivity. This will potentially increase the treatment efficacy, assuming that the selected targets are integral parts of the dysfuctioning networks involved in the pathophysiology of depression (Fox et al. 2012a; Luber et al. 2017). This group-based targeting of functionally relevant areas is a significant improvement on the “standard” approaches, providing spatially confined target areas when individual functional MRI (fMRI) data is not available. It is also more accessible than the conventional neuroanatomical methods, since it does not require profound knowledge on cortical anatomy.

It is unclear whether straightforward anatomical targeting is sufficient for effective nTMS treatments, since connectivity-based targeting has been shown to produce promising results (Fox et al. 2012a). More research is required to yield the relevant parameters for identifying the optimal treatment target; in addition to the connectivity of the treatment target with structures involved in the pathophysiology of depression, metabolic characteristics might provide useful parameters (Paillère Martinot et al. 2010).

As stated earlier, the areas of the Brainnetome Atlas are not consistent with the original BAs; however, the nomenclature is based on these areas, with the refinements of area 9/46 provided by Petrides and Pandya (1999). Our pipeline is straightforward to apply with any brain atlas, as the repertoire of atlases continues to evolve (Dickie et al. 2017); it also involves the Desikan-Killiany atlas (Desikan et al. 2006), which is a coarse anatomical atlas based on gyral geometry. Petrides (2019) presented a more detailed anatomical atlas based on the cortical morphology of the MNI brain. It provides a series of coronal sections, where the gyri, sulci, and the likely locations

Fig. 4. Visually determined treatment targets (black dots) and atlas-based areas A9/46 (red), A9 (yellow), and A8 (blue) of individual depression (S1–S10) and schizophrenia (S11–S13) patients. These targets were identified retrospectively by utilizing the method of Mylius et al. (2013).
of the cortical areas are identified. To compare these anatomically defined areas with the Brainnetome Atlas areas, we performed a coarse comparison of their locations in the posterior–anterior axis (Appendix D). Based on this comparison, the average locations of these areas seem to match relatively well, while some differences exist in their extents in the posterior–anterior direction.

Considering the other target areas obtained in the current study, the SMA and auditory cortex were visualized for the Tourette syndrome and tinnitus patients, respectively (Fig. B1 in Appendix B). Previous studies on these indications and OCD have mainly identified the treatment targets by utilizing the international 10–20 EEG system (Lefaucheur et al. 2014). In contrast to this approach, our atlas-based method considers the underlying gyral anatomy, enabling more accurate targeting when combined with neuronavigation. During neurosurgical mapping near the Wernicke’s area, the visualized areas provide additional guidance (Fig. B2 in Appendix B). In the motor cortex, A4 exhibits large spatial extent (Fig. B3 in Appendix B), and motor mapping is the most reliable method for identifying a muscle-specific treatment target. However, visualizing the motor cortex during nTMS could provide additional guidance for inexperienced users.

The proposed pipeline has limitations, the most important being the possible designation errors when registering the group-based atlas to the individual brain MRI volume. Because of these errors, the target areas may not be reliably identified for individuals with significantly deviating cortical morphologies. Especially, when applying an atlas based on healthy subjects to individual patients, this reliability could be further reduced due to disease-related functional plasticity. The second limitation is the time required to run the pipeline: in practice, the MRI and the pipeline need to be performed the day before the nTMS procedure. Further optimization of the FreeSurfer implementation could reduce the time required for running the pipeline. More clinical studies are needed to investigate whether the more accurate targeting improves the effects of rTMS and TBS therapies on the various indications. However, the potential of the demonstrated method is not limited to the identification of treatment targets; brain atlases can be used, for example, as seed points for diffusion tensor imaging (DTI) tractography, identifying individualized cortical targets with most probable connections to subcortical targets.

5. Conclusion

We demonstrate the application of the Brainnetome Atlas in identifying various treatment target areas. These areas include the DLPFC for the treatments of depression and schizophrenia, SMA for OCD and Tourette, and auditory cortex for tinnitus to be used with rTMS and TBS. Additional benefits may be in the identification of treatment targets for pain therapy and in guiding the mapping of language and motor areas. Finally, the individual target areas can be valuable in scientific research when targeting non-motor areas, such as the SMA for TMS-EEG.

Declaration of Competing Interest

Petro Julkunen has a patent with Nexstim Plc, manufacturer of nTMS systems. The rest of the authors declare no competing interests.

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Appendix A

Table A1

| Table A1 | Atlas indices. DLPFC, dorsolateral prefrontal cortex; M1, primary motor cortex; SMA, supplementary motor area. | Anatomical area | Indications | Atlas indices |
| --- | --- | --- | --- | --- |
| DLPFC (A9/46) | Depression Schizophrenia | A9/46dL, A9/46v_L (left hemisphere) and A9/46d_R, A9/46v_R (right hemisphere) |
| SMA (medial part of A6) | Tourette | A6m_L, A6dL_L and A6m_R, A6dL_R |
| Auditory cortex (A41/42) | Tinnitus | A41/42_L, A22c_L, A22r_L, TE1.0_TE1.2_L and A41/42_R, A22c_R, A22r_R, TE1.0_TE1.2_R |
| Wernicke (A22 and A40) | Neurosurgical mapping | A22c_L, A40c_L, A40d_L, A40rd_L and A22c_R, A40c_R, A40d_R, A40rd_R |
| M1 (A4), precentral gyrus | Research, motor mapping | A4dL_L, A4dL_R, A4dL, A4dL, A4rd_L and A4rd_R, A4d_R, A4dR, A4rd_R |

Appendix B

Table A1

| Subject | Left target | Right target |
| --- | --- | --- |
| Brainnetome Atlas area targeted by the method of Mylius et al. | Distance to A9/46 (mm) | Distance to A8 (mm) | Distance to A9 (mm) |
| Brainnetome Atlas area targeted by the method of Mylius et al. | Distance to A9/46 (mm) | Distance to A8 (mm) | Distance to A9 (mm) |
| 1 | A9/46 | - | 10 | 18 |
| 2 | A9/46 | - | 2 | 17 |
| 3 | A9/46 | - | 5 | 21 |
| 4 | A9/46 | - | 6 | 23 |
| 5 | A8 | 5 | - | 29 |
| 6 | A9/46 | - | 10 | 21 |
| 7 | A9/46 | - | 5 | 27 |
| 8 | A9/46 | - | 5 | 30 |
| 9 | A8 | 7 | - | 25 |
| 10 | A9/46 | - | 8 | 22 |
| 11 | A9/46 | - | 7 | 23 |
| 12 | A8 | 5 | - | 25 |
| 13 | A8 | 2 | - | 18 |
| Mean | 5 | 6 | 23 |
| Std | 2 | 3 | 4 |

J. Reijonen, M. Könönen, P. Tuunanen et al. Clinical Neurophysiology 132 (2021) 1612–1621
Fig. B1. Target area A6 (green) of individual Tourette syndrome patients (S14 and S15) and auditory cortex (A41/42 and A22, pink) of the tinnitus patient (S16) based on atlas information. The black dots indicate the treatment targets selected by a clinician.

Fig. B2. Wernicke’s areas (A22, red; A40, blue) of individual neurosurgical mapping patients based on atlas information. The black dots indicate the cortical sites associated with speech responses.
Appendix B

Figs. B1-B3

Appendix C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clinph.2021.01.037.

Appendix D

Tables D1 and D2

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**Fig. B3.** Motor hotspots and atlas-based target area A4 (purple) of individual motor mapping subjects. The black dots indicate the motor hotspots of the first dorsal interosseous (FDI) muscle.

**Table D1**

Y coordinates (posterior–anterior) of Average MNI Brain (Petrides, 2019) and Brainnetome Atlas (Fan et al. 2016) areas.

| Average MNI Brain area | Y coordinates | Brainnetome Atlas area | Y coordinate (left/right hemisphere) |
|------------------------|---------------|------------------------|--------------------------------------|
| 8B                     | 31–35         | A8m                    | 15/16                                |
| 8B                     | 31–35         | A8dl                   | 24/26                                |
| 8A                     | 15–23         | A8vl                   | 23/27                                |
| 9                      | 51            | A9m                    | 36/38                                |
| 9                      | 51            | A9l                    | 49/48                                |
| 9/46d                  | 31–51         | A9/46d                 | 43/37                                |
| 9/46v                  | 31–35         | A9/46v                 | 41/44                                |
### Table D2

| Area | Range, left | Middle point, left | Range, right | Middle point, right |
|------|-------------|--------------------|--------------|--------------------|
| A8m  | 1–30        | 16                 | 2–33         | 18                 |
| A8dl | 4–39        | 22                 | 7–39         | 23                 |
| A8vl | 7–37        | 22                 | 11–38        | 25                 |
| A8m  | 16–56       | 36                 | 17–55        | 36                 |
| A8l  | 25–68       | 46                 | 28–68        | 48                 |
| A9j  | 28–56       | 42                 | 15–52        | 33                 |
| A9j/46v| 23–57       | 40                 | 19–59        | 39                 |

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