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Case Study

A neurophenomenological fMRI study of a spontaneous automatic writer and a hypnotic cohort

Etzel Cardeña [a,*], Lena Lindström [a], Philippe Goldin [b], Danielle van Westen [c], Johan Mårtensson [d]

[a] CERCAP, Department of Psychology, Lund University, Sweden
[b] University of California Davis, USA
[c] Institution for Clinical Sciences, Diagnostic Radiology, Lund University, Sweden
[d] Department of Clinical Sciences Lund, Logopedics, Phoniatrics and Audiology, Lund University, Sweden

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ABSTRACT

Purpose: To evaluate the neurophenomenology of automatic writing (AW) in a spontaneous automatic writer (NN) and four high hypnotizables (HH). *Methods:* During fMRI, NN and the HH were cued to perform spontaneous (NN) or induced (HH) AW, and a comparison task of copying complex symbols, and to rate their experience of control and agency. *Results*: Compared to copying, for all participants AW was associated with less sense of control and agency and decreased BOLD signal responses in brain regions implicated in the sense of agency (left premotor cortex and insula, right premotor cortex, and supplemental motor area), and increased BOLD signal responses in the left and right temporoparietal junctions and the occipital lobes. During AW, the HH differed from NN in widespread BOLD decreases across the brain and increases in frontal and parietal regions. *Conclusions:* Spontaneous and induced AW had similar effects on agency, but only partly overlapping effects on cortical activity.

1. Introduction

Automatic writing (AW) can be defined as writing experienced as produced unintentionally by the writer. It is one of various automatisms including "channeled" speaking, drawing, painting, and musical composition (Hastings, 1991). In art, the surrealist movement in its origins purposefully studied and cultivated automatism in writing, drawing, and painting (e. g., Breton, 1933).

There are different types of AW, from simple doodling through ordinary writing to extraordinary writing. In this paper, we focus on extraordinary AW in the sense that what is written does not conform to any known alphabet we could find, yet is very precise, complex, consistent, and fast. Other examples of extraordinary AW include fast lettering written in mirror-like or upside-down fashion. AW, either with paper and writing instrument or through a contraption such as a planchette, has also been used as a way to try to induce anomalous experiences and cognition (Hastings, 1991). AW has at times manifested in individuals with dissociative or functional neurological disorders (Britton, 1997), but is not necessarily pathological. Rather, it is one of many automatisms exhibited spontaneously or trained through hypnosis or practice (Downey & Anderson, 1915; Koutstaal, 1992; Walsh et al., 2014).

AW, particularly when not referring to unintentional simple patterns or repetition, but to meaningful and sometimes unusual productions, has drawn the interest of eminent psychological scientists and artists, although with very scant systematic research. Among them, in earlier times, we can list William James, Pierre Janet, H. W. F. Myers, and Morton Prince; and, closer to our time, George A. Miller, Ernest Hilgard, Ulric Neisser, and even B. F. Skinner (Koutstaal, 1992). In various papers, William James (e.g., James, 1889, 1896) had already described characteristics and types of AW, including the cardinal aspect of experiencing that someone (or something) else was responsible for the writing (sometimes involving the *personation* or creation of impossible agents responsible for it), the ease with which many people whether as a Spiritualist practice or merely as a game could develop some ability, the anesthesia in the hand exhibited by some while writing automatically, and the fitful exhibition of seemingly anomalous communications (e.g., having a planchette write the color and suit of cards chosen at random and not shown to the writer). James, F. W. H. Myers, and other contemporary authors posited some type of secondary centers of

* Corresponding author at: Department of Psychology, Center for Research on Consciousness and Anomalous Psychology (CERCAP), Lund University, Allhelgona kyrkogata 16a, Lund 22100, Sweden.
E-mail address: Etzel.Cardena@psy.lu.se (E. Cardeña).

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consciousness to explain AW (Crabtree, 2007; Myers, 1903/1961).

Of particular interest to our study is James's description of extraordinary forms of AW including fast mirror-script and backward spelling. In one memorable case he had a man write on large sheets on a table while his face was buried hidden in the left elbow; he wrote continuously without breaks and at the end "he returned to the top of the sheet and proceeded downwards, dotting each i and crossing each *t* with absolute precision and great rapidity" (James, 1889, p. 554-555).

1.1. Psychological research on automatic writing

After the interest in AW at the end of the 19th and beginning of the 20th centuries, research on automatic processes - and states of consciousness in general - fell out of academic favor. This started to change decades later when Ernest Hilgard developed his neo-dissociation theory, partly based on consideration of cognitive and behavioral subroutines that could be enacted within the context of hypnosis or more everyday contexts (Cardeña, 2022; Hilgard, 1986). Another reason that dissociation/automatism has been eliciting more research and theoretical work is the recent interest in the sense of agency, a core aspect of the sense of self (e.g., Gallagher, 2000; Schneider & Shiffrin, 1977). People may be largely unaware of the activity of their hands or preoccupied with something completely different, or, when aware, have the impression that they are not the author or source of the activity. In other words, they might not have a sense of being the agent of what is produced, even when they can initiate or stop the writing. Thus, the experience of control over one's behavior or experience is related but not identical to agency. There are spontaneous pathological or non-pathological (i. e., anomalous) experiences of lack of agency (or ownership) and control that can be induced through various means, including hypnosis (Cardeña & Alvarado, 2014).

A cardinal aspect of the hypnotic experience is a sense of involuntariness and some hypnotic suggestions often attempt to overtly diminish the senses of agency and control (Weitzenhoffer, 1980). Verbalizations such as "it is happening on its own" or "just let it happen" seek to reduce the sense of agency, whereas challenge suggestions such as "your arm is stiff and rigid, just try to bend it, try" test a reduced sense of control. Hypnosis is particularly relevant to research on AW because it can be used *instrumentally* to instantiate unusual behaviors through specific suggestions offered to those highly responsive to hypnosis (Oakley & Halligan, 2009). As a case in point, Walsh et al. (2015), administered to individuals highly responsive to hypnosis (henceforth referred to as Highs) a hypnotic induction followed by suggestions to experience completing sentence stems as either voluntary, as if the answers had been placed in their minds by someone else (thought intrusion), or as if the hand were controlled by someone else (alien control). The thought intrusion condition was associated with decreased senses of thought ownership and control, but not of movement, with the opposite results for the suggestions for alien control. Using a different writing task, Polito et al. (2018) essentially replicated these findings. Another study used four conditions to evaluate the experience of agency/control and brain functioning: non-hypnosis, hypnosis with voluntary movements, hypnosis with involuntary movements, and hypnosis with involuntary and unaware movements (Deeley et al., 2013). The hypnotic conditions all related to lower senses of awareness and ownership than the no-hypnosis one.

Manipulations other than hypnosis can also alter the sense of agency and control. For instance, we may experience agency for actions we did not perform (Wegner et al., 2004; Wegner & Wheatley, 1999), or lack that experience for actions that were consciously willed, depending on whether timing is manipulated (Blakemore et al., 1999). There are individual differences, independent of manipulations such as hypnosis, associated with a reduced sense of agency and lower *meta*-cognition. In the latter case, dissociative absorption, in which the person becomes focused on internal or external stimuli while neglecting the surroundings, is an example (Bregman-Hai et al., 2020). Reduced experience of agency and control also differ in some alterations of consciousness including spirit possession, or in neurological conditions such as alien hand syndrome (for a review see Cardeña & Alvarado, 2014).

Studies in the last few decades have sought to elucidate whether dissociated aspects of cognition carry a cognitive load. Several findings have shown that enacting a task even "subconsciously" following a posthypnotic suggestion requires cognitive effort (Knox et al., 1975), particularly with more difficult tasks (Stevenson, 1976). Like Deeley et al. (2013), Walsh and collaborators (2014) reported that both hypnotic induction and specific targeted suggestions produced decreases in the senses of agency, control, and awareness. A review of the literature concluded that hypnotic responding requires varying levels of attention, awareness, and control, but is generally more automatic and requires fewer cognitive resources than non-hypnotic responding (Brown & Oakley, 2004), perhaps because of a more passive mode of attention (Bowers & Brennenman, 1981). It is clear though that induced AW, for instance by writing simple answers to questions in an unattended auditory channel, does not seem to fully address the characteristics of extraordinary AW.

1.2. Brain imaging research on agency and automatic writing

Neuroimaging studies have identified several brain regions associated with the sense of agency. These include areas in the motor system such as the supplementary motor area (SMA) and pre-SMA, premotor cortex (PMC) and the cerebellum, and areas implicated in selection and monitoring such as the dorsolateral prefrontal cortex (DLPFC) and insula (David et al., 2008; Seghezzi et al., 2019; Spence, 2002; Sperduti et al., 2011). The motor areas are likely linked to a lower-level aspect of the sense of agency, dependent on afference-efference brain network loops through which we can anticipate our own actions, while the monitoring areas are involved with explicit judgment of agency (David et al., 2008; Pacherie, 2011). The SMA/pre-SMA is particularly relevant and seems to be involved in both explicit and implicit senses of agency (Kühn et al., 2013). Temporarily disturbing the pre-SMA with non-invasive techniques (transcranial direct current stimulation and transcranial magnetic stimulation) results in a reduced sense of agency (Cavazzana et al., 2015; Moore et al., 2010), and lesions in the SMA have been related to the "alien hand syndrome," in which one's arm is experienced as acting independently of or even against one's will (Della Sala et al., 1991). Several findings reveal also that greater activity in the temporoparietal junction (TPJ, including posterior/inferior parietal cortex, angular gyrus, and posterior superior/middle temporal gyrus) relates to attribution of agency to an external source (Haggard, 2017; Sperduti et al., 2011; Walsh et al., 2015; Zito et al., 2020). Thus, different brain regions support different aspects of the sense of agency.

In their investigation of AW induced by hypnosis, Walsh et al. (2015) collected functional Magnetic Resonance Imaging (fMRI) data and reported that suggestions for thought insertion related to reduced activation of brain networks associated with self-related processes, motion, and language. In contrast suggestions to experience the hand as controlled by someone/something else (i. e., "alien hand") were associated with increases in the cerebellar-parietal network and decreases in areas related to voluntary movement. For both types of suggestions, there were decreases in SMA activation and alterations in connectivity between SMA and language processing areas. In the study by Deeley et al. (2013) mentioned earlier, the brain activation pattern during voluntary movements in no-hypnosis did not differ from that during voluntary movements under hypnosis, but the results suggested that involuntary movements related to reduced connectivity between SMA and motor implementation areas. For the hypnosis conditions, reduced awareness of movements related to decreased activity in left inferior and superior parietal lobes, and in left superior temporal and occipital areas.

We found only two studies on naturally occurring automatisms, both using single photon emission computed tomography (SPECT). The first one (Newberg et al., 2006) found that during glossolalia (automatic, pseudo-linguistic utterances), five psychologically healthy female Pentecostalist or Charismatic practitioners had significant decreases in the prefrontal cortices, left caudate and left temporal pole, and increases in the left superior parietal lobe and right amygdala compared to intentional singing. The second study is even more relevant to ours as it evaluated *psychography* (i. e., regular writing experienced as produced by spirits). Peres and collaborators (2012) compared five experienced psychographers with five less experienced ones during an altered state of consciousness and during ordinary writing. As compared with the latter, during psychography the expert sample evinced lower activity levels in the left culmen, left hippocampus, left inferior occipital gyrus, left anterior cingulate, right superior temporal gyrus, and right precentral gyrus. The authors concluded that these changes could not be explained by lower cognitive activity or relaxation when taking into consideration the results with the non-expert sample. It should be mentioned that SPECT has less spatial and temporal resolution than fMRI BOLD imaging.

1.3. The present study

In this study we focused on an exceptional automatic writer (NN) and compared her with a group of high hypnotizables (HH) who were able to perform induced AW. Because the AW of NN is extremely unusual, it would be very difficult to find similar individuals, so we recruited participants who could write automatically in response to hypnotic suggestions. This study follows a case-controls design, given the exceptional characteristics of NN, an approach that has been fruitfully used in neuropsychology (e.g., Crawford et al., 2003), and we adopted a neurophenomenological approach in the sense of the careful integration of first- with third-person techniques (Cardeña et al., 2013; Lutz & Thompson, 2003).

We employed fMRI and phenomenological queries and interviews to investigate brain activity and experience during AW and during a symbol copying task. Because, to our knowledge, there has been no previous fMRI study of a spontaneous automatic writer, this is to a large degree an exploratory study. We aimed to: 1) evaluate the experience and associated brain dynamics of *spontaneous* (NN) automatic writing as compared with willed copying of similarly complex symbols, 2) differentiate the experience and associated brain dynamics of *induced* (HH) automatic writing from that of willed copying of similarly complex symbols, and 3) compare descriptively the experience and brain dynamics of HH and NN.

Based on prior research we also had the following hypotheses:

1. Both spontaneous and hypnotically-induced AW will be experienced as involving less agency and control than a copying task.
2. NN and the HH will have significantly greater fMRI BOLD signal responses in TPJ and smaller responses in SMA, PMC, DLPFC and insula during AW than during copying.

In addition, we expected that the brain dynamics of NN and the HH would be similar during copying but would vary in unspecified way during automatic writing considering the difference of spontaneous versus induced AW.

2. Materials and method

2.1. Participants

The spontaneous automatic writer, NN, a 32-year-old, right-handed female, approached the first author to try to get an explanation for her automatic writing. She was pleasant, cooperative, and curious, reported no history of psychiatric or neurological disorders, and was completely lucid during all interactions with the researchers. She comes from a family that practices Pentecostalist Christianity and has at times spoken in tongues. In her group, AW is seen as something closer to occultism rather than an accepted religious practice. At age 16, she suddenly started writing automatically during a Swedish language class while she had a pen in her hand, and has continued to do so sporadically. Both hands can spontaneously do AW, but because she is right-handed (scored + 100 in the Edinburgh Handedness Index (EHI), see below) she typically holds a pen in her right hand; she can write automatically left to right or right to left with equal ease . She does not experience alterations of consciousness while doing AW and could maintain a normal conversation with the first author in the meantime.

NN's AW is rapid (considerably faster than her ordinary writing) and flows from left to right and top to bottom (see Supplement A). The complex characters she writes vary considerably (at least hundreds of recognizably distinct characters with small variations, as compared with the 29 letters of the Swedish alphabet; see Fig. 1). Her AW differs from the ordinary writing that most automatic writers (like the psychographers mentioned above) engage in. They vaguely resemble Eastern characters, but an expert who examined her writing determined that they are not Sanskrit, Chinese, Japanese, Korean, or Tibetan (Gerald F. Solvin, Ph. D., personal communication July 7, 2021). She "allows" her AW to occur without changing her state of consciousness and looks at what she is doing if she wants to maintain her writing aligned, but can also do it without looking. She is puzzled as to the meaning or purpose of her AW.

In addition to NN, four HH were recruited, matched for gender and handedness ($M = +69$, $SD = 15.52$ in the EHI), $M_{age} = 31.25$, $SD = 15.41$, range 19–51. The inclusion criteria were that they score high in standardized group and individual instruments, be able to follow hypnotic suggestions to write automatically (typically doodles with occasional simple figures like a flower; see Fig. 2), and not report emotional distress. They scored as high hypnotizables according to the Harvard Group Scale of Hypnotic Susceptibility (see below), $M = 9.25$, $SD = 1.48$, and 47 or more in its experiential measure, the SES (see below), $M = 48.5$, $SD = 1.28$, placing them in the 5–10% top range of hypnotic ability. Their high hypnotizability was corroborated by the more demanding Stanford Hypnotic Susceptibility Scale: C (see below). Recruitment stopped when COVID restrictions limited further participation, but we concluded nonetheless that these HH could represent how Highs would likely react to the experimental tasks. All participants signed an informed consent, and the project was approved by the Swedish Ethical Review Authority (Dnr 2020–00525).

2.2. Measures

Interview questions. Based on Walsh et al. (2015), we developed 9

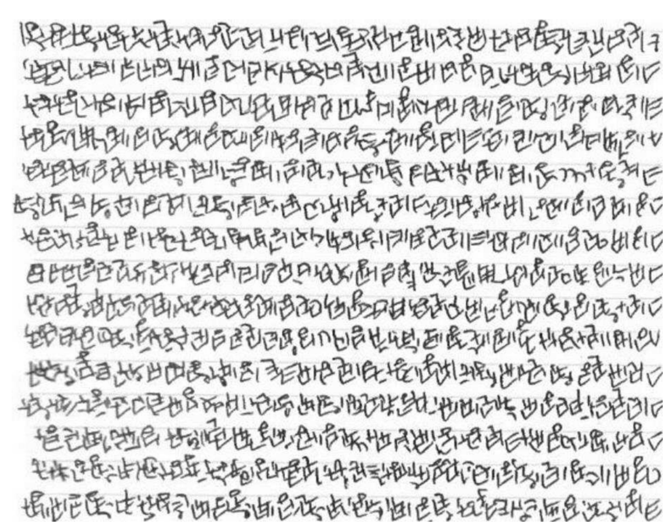

Fig. 1. Sample of NN's Automatic Writing.

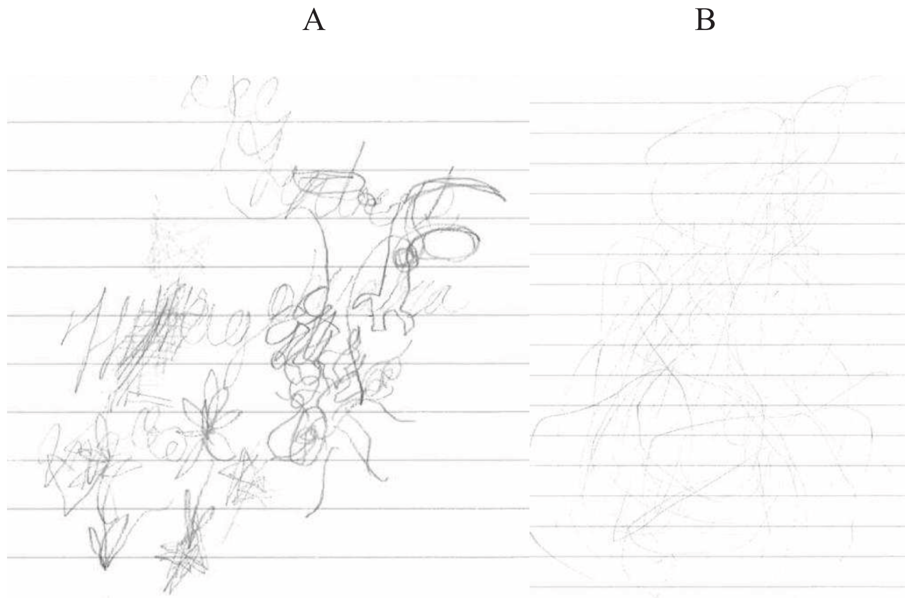

Fig. 2. Samples of the Automatic Writing of Two Highs.

open-ended questions to assess differences between voluntary and automatic writing in sensory input, intention, sense of ownership, and thinking, asked at the end of the fMRI scan: What differences did you experience between the copying and the × (hypnosis or spontaneous automatic) task? During the × task: what did you think about in the meantime? Did you feel how the hand moved? Was it like someone else decided how to move your hand? Was it like someone else decided what you should write? Did it feel like it was your hand that wrote? Did you know approximately what you wrote looked like? Could you predict the movement before it occurred? Is there anything more you want to add?

Agency questions. Based on their relevance for our study, we selected 7 of the original 48 items of the *Sense of Agency Rating Scale* (SOARS; Polito et al., 2013), a valid and reliable measure of experiencing agency and control. They were reworded to concern actions, and were translated into Swedish by LL, and scored on a scale from 1 = not at all to 4 = completely. The questions were: "My actions required my effort," "My actions were under my control," "I was surprised by my responses," "My actions occurred by themselves," "My responses felt very different to normal everyday experiences," "My responses felt unavoidable," "I felt in charge of my actions." These questions served not only to verify that our AW condition was indeed experienced that way, but to compare whether NN and HH differed in this parameter.

The *Brief Symptom Inventory* (BSI; Derogatis, 1975) is a commonly-used 53-item inventory that measures distress, with a scale from 0 to 4 for each item. The BSI was not scored but used to screen and exclude from the study potential participants with marked levels of distress (i. e., having scores of 2 or more in various items).

The *Edinburgh Handedness Questionnaire* (Oldfield, 1971) consists of 12 actions that can be performed with the right or left hand, foot, or eye, (e. g., writing, kicking), with scores equal or > 40 corresponding to overall right-handedness.

The *Harvard Group Scale of Hypnotic Susceptibility* (HGSHS; Shor & Orne, 1962) is a group measure of hypnotizability consisting of a relaxation-based induction followed by 12 self-scored suggestions of increasing difficulty. Responses to each suggestion are scored by the respondent as having happened or not. The scale is very widely used and has good psychometric properties (Council, 1999).

The Revised Stanford Profile Scale of Hypnotic Susceptibility: Form 1 (R-SPSHS-1; Weitzenhoffer & Hilgard, 1967) is a measure of high hypnotic susceptibility. We only used its arm levitation induction to train the Highs to experience motor automaticity.

The *Stanford Hypnotic Susceptibility Scale: Form C* (SHSS:C; Weitzenhoffer & Hilgard, 1962) measures hypnotic responsiveness individually. The scale involves an induction and twelve suggestions (with greater difficulty than the HGSHS) and is scored by the hypnotist. It has excellent psychometric properties (Council, 1999).

The *Subjective Experiences Scale* (SES; Kirsch et al., 1990) is a valid and reliable self-scored questionnaire that assesses how much participants experienced the suggestions given in the HGSHS as happening by themselves, on a five-point bipolar response (1–5).

2.3. *Hypnotic procedures*

After an initial group hypnotizability testing, all four HH had an additional individual hypnotic session with the SHSS:C to ascertain that: a) they were highly hypnotizable (unscored because as soon as it was evident to the hypnotist, EC, that they were passing most suggestions easily he terminated the procedure) and b) to determine if they were experiencing emotional distress through the BSI (none of them did). Three additional training hypnotic sessions started with an arm levitation induction from the R-SPSHS-1, followed by phrases from the Alert Hand Induction (Cardeña et al., 1998) to elicit automatic movements of the hand, before giving the suggestion that the dominant hand holding a pencil feels "like writing letters, patterns, or shapes on its own and starts to move…" (see Appendix 1). At that point participants were allowed to move their hands for about a minute. Thus, the procedure was closer to the "alien hand" protocol than to "thought insertion" in the study by Walsh et al. (2015), but without the assumption that "someone else" is moving the person's hand.

All four HH responded to the suggestion with movements of their hands holding a pencil on a piece of paper and writing/drawing something. During the practice sessions, the HH were also trained to use self-reports of hypnotic depth, varying from 0 (fully awake) to 10 (as hypnotized as they could ever be). NN's hypnotizability was also evaluated with the SHSS:C and scored 11 out of 12 (missing only the auditory hallucination item) in the SHSS:C, demonstrating very high hypnotic susceptibility, but hypnosis was otherwise not used during the experiment with her. Fig. 2 shows samples of AW from two different Highs. A is the most elaborate of all samples, B is a more typical type of traces going up/down and horizontally.

2.4. fMRI

Participants were screened for MR safety and instructed on safety procedures and what to expect of the MRI session and the specific writing tasks. While in the scanner lying supine, all participants alternated between the automatic writing task and a copying task, writing with a pencil on a paper fitted to a small board on their laps. They could not see what they wrote or copied; while they copied they had to look at the model, and during AW they were repeatedly asked to keep their eyes open, even during hypnosis (see Appendix 1). The copying task, created for this study, was a list of nonsense symbols adapted from Devanagari script used in the Indian subcontinent and somewhat similar to the symbols produced spontaneously by NN (see Fig. 3). The symbols were presented on a screen and participants were asked to copy them. There was no possibility to use perfect, parallel control/experimental conditions because neither NN nor the HH could agentically write the type of symbols in NN's AW without copying them. Furthermore, copying them would be different to NN, who had experience seeing them, than to the HH, for whom they would be novel. Thus, the rationale behind using these symbols was to have a set that would have similar complexity to the symbols used automatically by NN and would impose a similar cognitive demand on NN and the HH.

The block design of the fMRI session is presented in Fig. 4. Both tasks were prompted on a screen and lasted 60 s. For the HH, AW was preceded by the hypnotic suggestions to write automatically mentioned earlier, followed by a brief reversal dehypnosis procedure and a numerical check that they felt now fully awake by responding 0 or 1 in the scale of hypnotic depth (see Appendix 1). For NN, there was only a visual message "Let your hand write automatically" (which was also presented for the HH during the AW scan).

The two tasks were repeated three times each for NN and two times for the HH, in order to restrict the number of times the participants had to go in and out of hypnosis. After each block, participants used button presses to rate their experience during the preceding block for the seven agency questions. NN was scanned on two occasions separated by six months and the HH on one occasion each (see Fig. 4).

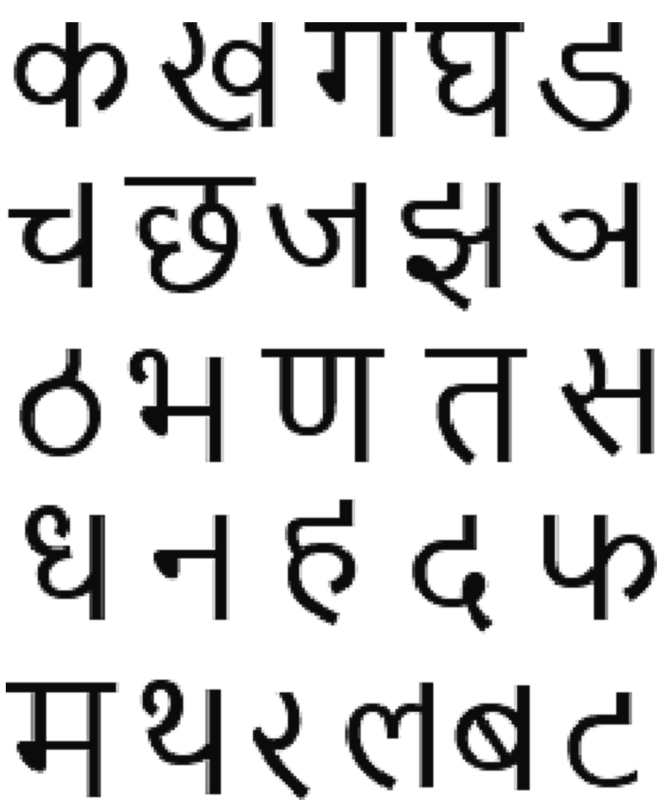

Fig. 3. Symbols Adapted from Devanagari Script Used for the Copying Task.

Data were acquired on an actively shielded 7 T Philips MR scanner (Achieva; Philips Healthcare, Best, the Netherlands) with a 2-channel transmit, 32-channel receive head coil (Nova Medical, Wilmington, MA, USA) and two dielectric pads (Multiwave Imaging, Marseille, France), using gradient echoplanar imaging. The repetition time was 1.2 s during which one volume consisting of 44 interleaved oblique orbitomeatal axial slices with $2 \times 2 \times 2$ mm^3 voxel dimension and 0.2 mm slice gap were acquired. The echo time was 25 ms, flip angle 65 degrees, and field of view $224 \times 232 \times 97$ mm. A total of 48 volumes were collected during each 60 s block. Each functional run was preceded by five volumes to allow for the MR signal to reach a steady state. These extra volumes were removed prior to preprocessing. A field map was acquired before each functional run to measure and remove magnetic field inhomogeneities in the signal across the brain. For each participant, an anatomical T1-weighted image was also acquired, with the following parameters: voxel dimension $1 \times 1 \times 1$ mm^3, echo time 1.97 ms, repetition time 5 ms, acquisition time 1.43 min, flip angle 6 degrees and field of view $199 \times 251 \times 200$ mm.

2.5. Data analyses

2.5.1. Self-report responses

We used t tests for comparisons with a normal distribution and the Wilcoxon nonparametric test for non-normal distributions, when analyzing NN and HH separately. When comparing NN and HH, we used the Crawford and Garthwaite's (2002) t test for a single case versus a small n comparison group. The criterion for significance was set at $p < .05$ and we used Hedges's g for effect size because it eliminates a bias for small sample sizes found in Cohen's d (Lin & Aloe, 2021).

2.5.2. fMRI BOLD signal preprocessing and statistical analysis

All volumes were preprocessed using realignment to the middle slice, unwarping, and slice-timing correction, and normalized to MNI space. Spatial smoothing was carried out using a Gaussian kernel with FWHM of 6 mm. Voxel size before as well as after preprocessing was 2x2x2 mm^3. Because of the loud noise during imaging in the scanner, the MR scanner was paused during each hypnotic induction and dehypnosis. For the HH, four separate one-minute scans were conducted, while for NN the scanning was uninterrupted over all six blocks. After the scanning, we asked all participants how they experienced the conditions in a recorded interview (see Section 2.2).

For the data acquired from NN, a general linear model was applied in SPM12 (version 7771, Penny et al., 2011) with two conditions: Copying and Automatic Writing. For the HH, the four separate one-minute scans were concatenated to one four-minute file using FSLMerge (Jenkinson et al., 2012). A general linear model with two conditions, Copying and Hypnosis, was applied to this file in SPM. We are aware that this method compromises the assumptions of linear modelling of the BOLD response, as the four blocks were in fact not acquired back-to-back but with interruptions for hypnosis, dehypnosis, and agency questions. However, we think this effect was negligible as the duration of each block far exceeded the duration of a BOLD response.

Movement parameters (3 translations and 3 rotations) were covaried for all participants. Head movements for NN, whose hand moved considerably during AW, reached maxima of 1.45 mm (first session) and 3.88 mm (second session) and 2.16 vs. 2.35 degrees of rotation (root mean square Copying, $M = 1.06$, $SD = 0.43$, AW $M = 1.17$, $SD = 0.43$). For the HH, head movement did not exceed 1 mm or 1 degree (root mean square Copying $M = 0.20$, $SD = 0.13$, AW $M = 0.06$, $SD = 0.04$). Visual inspection of HH's head movement parameters suggested a clear difference between the hypnosis and copying blocks with deep, regular breathing visible during hypnosis but not copying.

Data from the two sessions with NN were entered into one design matrix, and data from the four HH into another. One-sample t-tests were then performed on a canonical haemodynamic response function in

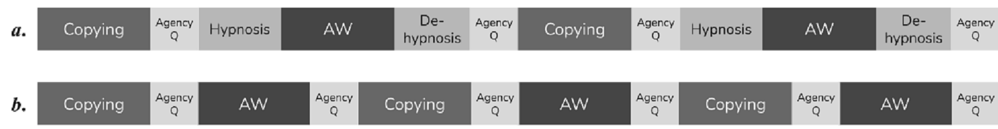

Fig. 4. Block Design of the fMRI Sessions. Note: a) Task design for the HH. b) Task design for the Automatic writer. AW = automatic writing, spontaneous or hypnotically-induced. The copying task was the same for all participants. Agency Q = agency questions. The copying task was the same for all participants.

SPM12. BOLD signal responses from the AW blocks were contrasted with those from the copying task on a whole-brain level. Clusters of functional BOLD signal were thresholded using a per voxel alpha of $p < .001$ (FWE corrected) and minimum cluster volume of $k > 20$ voxels (i.e., $2 \times 2 \times 2$ mm$^3 \times 20 = 160$ mm^3) for both analyses.

3. Results

3.1. Spontaneous automatic writer

3.1.1. Self-report responses

NN's mean agency ratings for the experimental conditions are displayed in Fig. 4. She was invariant in her responses for the copying conditions, giving ratings of maximum agency and control to all questions (i. e., = 28). The ratings for AW showed some variation for items 1–3 and 6 ("My actions required my effort," "My actions were under my control," "I was surprised by my responses," and"My responses felt unavoidable,"), no variation for items 5 and 7 ("My responses felt very different to normal everyday experiences," "I felt in charge of my actions"), $M = 1$, $SD = 0$, and almost no variation for item 4 ("My actions occurred by themselves"), $M = 1.22$, $SD = 0.44$. Overall, NN reported significantly less control and agency for AW, $M = 11$, $SD = 1.18$, than for copying, $M = 28$, $SD = 0$, $W = 0$, $p < .01$, $g = 14.4$ (see Fig. 5).

Her post-session interviews were consistent with the agency ratings. For her, AW is something that she allows to happen and can stop, but is experienced as alien and not requiring any effort; in contrast, during copying she needed to make an effort and focus on the symbols to copy them correctly. During AW, she could not predict her hand movements nor the resulting characters, and was aware of her hand although she was thinking mostly about other things such as her family. She experiences her AW as something not created by her but like a flow, a presence outside of herself than can intensify at times when she allows it, and which is always present in some way. She mentioned that in general she can think about anything while doing her AW, although at times experiences going deeper into herself and feeling calmer and more positive. She does not feel responsible or relevant for the AW, and cannot control it except for allowing it to happen or stopping it. In contrast, she experienced copying as very efortful and self-directed.

3.1.2. Functional brain responses

For NN, in contrast to copying AW was characterized by decreased BOLD signal responses in these agency-related areas: left premotor cortex, left anterior insula, and right SMA, as well as left superior parietal lobe, somatosensory cortex, inferior frontal lobe and left putamen. BOLD signal increases for AW vs. copying were found for the left and right TPJ, the occipital lobes, frontal and temporal lobes, bilateral thalamus, left caudate nucleus, right putamen, and cerebellum. All significant clusters for NN are presented in Table 1 and Fig. 6.

3.2. Highly hypnotizables

3.2.1. Self-report responses

Six depth ratings were not recorded or discerned when reported, five of them during the second session. Nonetheless, it was clear that the HH experienced being in a "deeper" state of hypnosis after the hypnotic induction and suggestions, $M = 7.2$, $SD = 1.81$ than after coming out of hypnosis, $M = 0.37$ $SD = 0.51$, $t = 10.26$, $p = .0001$, $g = 5.12$. They also reported significantly greater control and agency during copying, $M = 24.87$, $SD = 1.97$, than during AW, $M = 13.37$, $SD = 2.66$; $t = 6.88$, $p = .01$, $g = 4.91$. In the post-session interviews, they stated that, as compared with AW, while copying they had greater awareness of the hand writing as they had to focus on the symbols to write, for instance thinking of "where the line had to go" in the symbols, which required conscious effort. In contrast, during hypnosis they felt more relaxed, did not have many thoughts, and attention was less focused, with one of them describing it as "not concerned about the ongoing writing." They mentioned being aware of the hand momentarily, or sensing it far away or retrospectively only, did not experience that anyone else was moving the hand, and feeling neutral about who was doing it, like it was happening by itself, with no one forcing them to do it, being able to stop

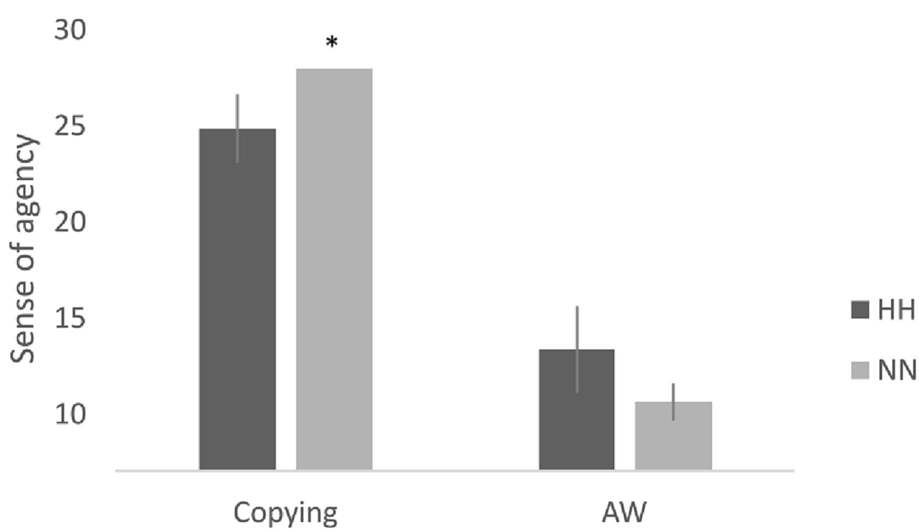

Fig. 5. Mean Agency Ratings for Participants with 95% Confidence Intervals. Note. AW = automatic writing. HH = high hypnotizables. * = No confidence intervals because there was no variance in NN's response.

Table 1
Significant Cluster Differences Between Copying and Automatic Writing for NN.

Contrast	Lobe	Area	Cluster size (mm^3)	*x*	*y*	*z*
NN Decreases	Frontal	LInferior frontal lobe; Anterior insula	1248	−28	6	28
(Copying > Automatic)	Parietal	LPremotor cortex; Frontal eye fields	624	−28	−4	54
	Temporal	RSupplementary motor area	184	22	4	40
	Subcortical	LSomatosensory cortex (hand area)	1424	−52	−26	40
		LSuperior parietal lobe	464	−34	−42	42
		LMiddle/anterior insula	176	−36	−2	4
		LPutamen	280	−30	−12	6
NN Increases	Frontal	RMiddle/inferior frontal gyrus	2592	32	−2	34
(Automatic > Copying)	Parietal	L/RAnterior/middle cingulate cortex	392	−2	−8	28
	Temporal	LSuperior frontal g.: Middle cingulate c.	296	−18	14	40
	Occipital	LTemporoparietal junction	1352	−32	−66	24
	Subcortical	RTemporoparietal junction	1184	36	−54	26
		LTemporoparietal junction	2200	−44	−38	8
		RMiddle temporal gyrus	1312	36	−56	6
		L/RLingual g.; Calcarine s.; Cuneus	14,264	16	−86	8
		RSuperior occipital lobe	424	36	−70	14
		RLingual gyrus	360	20	−62	0
		RMiddle occipital lobe	216	34	−78	0
		LLingual gyrus	200	−20	−56	0
		RThalamus	1344	24	−20	10
		LThalamus; Caudate nucleus	768	−24	−8	24
		LCaudate nucleus	448	−24	12	20
		-Cerebellum (Anterior vermis)	264	0	−460	−146
		RPutamen	208	34	−52	−14
		LCerebellum	200	−12		

Note: $p < .001$, FWE corrected; cluster size thresholded at 20 voxels = 160 mm^3. *X*, *y*, *z* indicate MNI.
coordinates at peak voxel within a cluster.

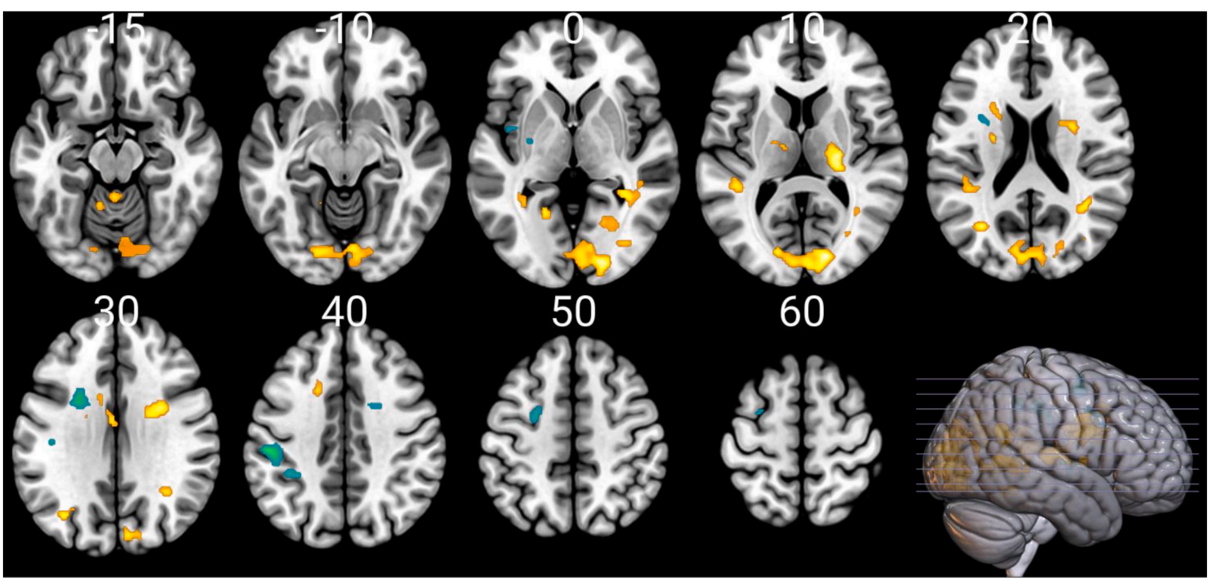

Fig. 6. fMRI BOLD Signals for NN. Note: Red-yellow areas denote increased activity and blue-green areas denote decreased activity during automatic writing vs. copying, $p < .001$ FWE-corrected, $k > 20$ voxels, slices seen from above. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

it, and at least at times not knowing what their writing looked like or being able to predict what they would write, or just knowing very vaguely or in retrospect what they had written. Because of missing data, we could not compare quantitatively depth reports from the first and second sessions, but during the interview all HH reported feeling more hypnotized during the second than the first AW session (suggesting that in hypnosis-fMRI studies conducting more than one hypnosis trial may be important).

3.2.2. *Functional brain responses*

For the Highs, as compared with copying AW was associated with decreased BOLD signal responses in premotor cortex, DLPFC, insula, SMA, superior parietal lobes, cingulate cortex, thalamus/caudate nucleus, occipital lobes and left somatosensory cortex. It was also associated with increased BOLD responses in the left and right TPJ, frontal and parietal lobes, including the primary motor cortices and right somatosensory cortex, occipital lobes, and the right hippocampus and amygdala. Significant clusters for the Highs are presented in Table 2 and Fig. 7.

3.3. *Comparison of the automatic writer and the highly hypnotizables*

3.3.1. *Self-report responses*

Fig. 5 shows that the 95% confidence intervals (CI) in the responses

Table 2
Significant Cluster Differences Between Copying and Automatic Writing for the Highs.

Contrast	Lobe	Area	Cluster size (mm^3)	x	y	z
Highs Decreases	Frontal	LPremotor cortex	14,440	−54	4	42
(Copying > Automatic)	Parietal	LPrefrontal cortex; DLPFC	1624	−42	34	32
	Temporal	RPremotor cortex; Suppl. motor area	528	22	2	66
	Occipital	RPremotor cortex	496	30	−4	46
	Subcortical	RFrontal pole	456	14	62	16
		RSuperior frontal lobe; DLPFC	344	18	28	60
		LAnterior cingulate cortex	280	−12	28	10
		ROrbitofrontal cortex	216	24	38	−6
		RAnterior cingulate cortex	208	16	28	16
		RPremotor cortex	192	50	8	32
		RFrontal pole	184	6	60	26
		LSuperior parietal lobe; Intraparietal s.	12,224	−40	−44	58
		RSuperior parietal lobe	4024	20	−58	58
		LSuperior parietal lobe	2488	−22	−78	50
		RIntraparietal sulcus	1000	34	−46	56
		RPosterior cingulate cortex	592	2	−38	24
		LSomatosensory cortex	216	−66	−18	26
		LSomatosensory cortex	160	−66	−28	32
		LMedial temporal lobe	3088	−24	−34	16
		LAnterior insula	936	−26	32	−2
		LInsula	480	−42	10	−2
		LInferior temporal lobe; Fusiform gyrus	392	−44	−38	−18
		RMedial temporal lobe	232	24	−8	20
		LMiddle temporal gyrus	184	−62	−44	−10
		LInferior occipital lobe; Fusiform gyrus	4120	−28	−94	−6
		RInferior occipital lobe; Fusiform gyrus	2080	32	−90	−6
		RThalamus; Caudate nucleus	520	16	−22	20
Highs Increases	Frontal	LPrimary motor cortex	3632	−12	−22	68
(Automatic > Copying)	Parietal	RInferior frontal lobe	1736	72	8	6
	Temporal	LFrontal pole	1592	−24	70	2
	Occipital	RFrontal pole	1544	22	70	6
	Subcortical	RFrontal pole	496	38	42	6
		RSomatosensory c.; Primary motor c.	2496	60	−10	46
		LTemporoparietal junction	640	−40	−46	28
		RSomatosensory cortex	424	66	−4	26
		RTemporoparietal junction	176	68	−30	16
		L/RSuperior occipital lobes; Lingual gyri	30,976	18	−86	30
		LInferior occipital lobe	440	−36	−58	6
		RMiddle occipital lobe	232	46	−74	4
		RHippocampus; Amygdala	384	30	−4	−20

Note: $p < .001$, FWE corrected; cluster size thresholded at 20 voxels = 160 mm^3. *X*, *y*, and *z* indicate MNI coordinates at peak voxel within a cluster.

fMRI BOLD Signals for the Highly Hypnotizables

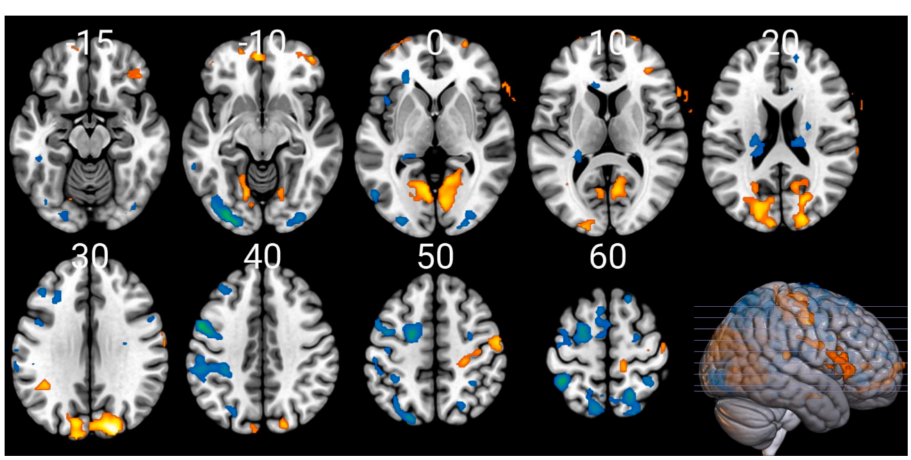

Fig. 7. fMRI BOLD Signals for the Highly Hypnotizables. Note: Red-yellow areas denote increased activity and blue-green areas denote decreased activity during automatic writing compared to copying, $p < .001$ FWE-corrected, $k > 20$ voxels, slices seen from above. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

of agency of NN and HH during AW partly overlap; for copying, no CI could be computed for NN because she gave the highest score every single time. The scores between NN and HH did not differ significantly either for AW, $t = 0.80$, $p = .48$, $g = 0.89$, or copying, $t = 1.42$, $p = .25$, $g = 1.59$. The interview responses of NN and the Highs had both similarities and differences. For NN, AW is something that she allows to happen and can stop, and HH stated that they could stop the AW at any time: neither could predict the outcome of the AW. Nonetheless, while writing automatically, NN stated that she could think about anything whereas the Highs mentioned not having many thoughts. All participants reported having to focus on the images during copying, which required more effort than AW.

3.3.2. Functional brain responses

For all participants, AW was associated with BOLD signal decreases in left premotor cortex and insula and in right premotor cortex and SMA, and with increases in the left and right TPJ and the occipital lobes. Figs. 6 and 7 are presented earlier and Appendix 2 includes individual images of the 4 HH to allow individual comparison with NN's images. Because of the small sample size and consequent low power and possibility of Type II errors (cf. McIntosh & Rittmo, 2021), no statistical comparisons between NN and the HH were made, but descriptively the HH differed from NN in showing > 10-fold widespread decreases during AW across the brain (a total of 6,463 voxels with decreased activity above our chosen statistical threshold, vs. 550 for NN). Decreases were observed in, among other areas, prefrontal cortex, superior parietal lobes, cingulate cortex, right thalamus, and left somatosensory cortex. The HH also showed some increases in the frontal and parietal lobes, including the primary motor cortices and right somatosensory cortex, as well as in right hippocampus and amygdala, which was not the case for NN.

4. Discussion

The goal of this study was to evaluate and compare the neurophenomenology of automatic writing, whether spontaneous or hypnotically induced. We corroborated some previous findings in all participants, but also found some notable differences between NN and the Highs.

4.1. Hypotheses

4.1.1. Hypothesis 1. Decreased sense of agency during AW compared to copying

As hypothesized, across all participants, compared to copying AW was associated with lower self-reported sense of agency. Copying symbols was described as requiring considerably greater agency and focus by all participants.

4.1.2. Hypothesis 2 decreased activity in agency-related brain areas and increases in TPJ

For all participants, AW was associated with lower BOLD signal in left premotor cortex and insula and in right premotor cortex and SMA, all previously implicated in the sense of agency (David et al., 2008; Seghezzi et al., 2019; Spence, 2002; Sperduti et al., 2011). AW was also associated with increased BOLD signal in the left and right TPJ and the occipital lobes, supporting previous findings on non-agency (e.g., Haggard, 2017; Seghezzi et al., 2019; Walsh et al., 2015). It may be that such increase works against a coherent sense of bodily self and agency (cf. Blanke et al., 2005). For the HH, but not for NN, there were also decreases in bilateral DLPFC during AW, perhaps representing lower involvement of executive functions such as decision making and working memory in hypnosis (cf. Parris, 2017), compared with the copying of new symbols.

During AW, there was decreased activity in the superior parietal lobes, left-lateralized for NN, bilaterally for the HH, supporting previous findings (e.g., Deeley et al., 2013). Together with the prefrontal decreases, these results are in line with the assumption that the cognitive control, task-positive fronto-parietal network is less active when a person is engaged in an automatic behavior compared with a more demanding task such as copying complex patterns (cf. Menon & D'Esposito, 2022).

4.2. Differences between induced and spontaneous AW

The HH showed some increases in prefrontal areas during AW, especially the frontal poles, suggesting some level of cognitive control or monitoring during the task, whereas for NN there were no increased prefrontal cortical activations during AW compared to copying. Also of note, the HH differed from NN in widespread decreases across the brain, including thalamus and posterior, anterior, and middle cingulate cortex, perhaps reflecting their deep state of hypnosis. Decreased activity in the anterior cingulate cortex was associated with a deep hypnotic state in an fMRI study by Jiang et al. (2017), and highlighted in a recent review of functional brain activity effects of hypnosis (Wolf et al., 2022). Deactivation in the posterior cingulate cortex, a main hub of the default mode network, is common during states of decreased self-salience (Garrison et al., 2013; Millière, 2017) including focused attention meditation (Fox et al., 2016).

4.3. Relation to previous automatism findings

Decreased prefrontal cortical activity was reported in the glossolalia study by Newberg et al. (2006), but our results show a more complex pattern regarding prefrontal activity. Also, in contrast to their results, NN showed *increased* activity in left caudate nucleus, the HH showed *decreases* in right amygdala, and NN and the HH showed *decreases* in left superior parietal lobe. There were likewise few overlaps between our study and the psychography study of Peres et al. (2012), except in that both the psychographers and our Highs showed decreased activity in anterior cingulate cortex and inferior occipital gyrus. However, contrary to the psychographers, NN showed increases in areas close to the left anterior cingulate and culmen, and the Highs showed increases in the precentral gyrus. These differences may partly be explained by the different imaging modalities used, as well as the different motor activity during glossolalia compared to writing.

In line with the previous study on hypnosis-induced automatic writing by Walsh and colleagues (2015), both NN and the HH showed decreased activity in left somatosensory cortex and increased activity in angular gyrus during AW. We also replicated their finding of increased activity in the lingual gyrus for the "alien hand" condition for both NN and the HH, consistent with their experience that they are not the source of that activity. Increased occipital activity beyond the lingual gyrus was a common finding for NN and the HH, being bilateral but slightly more prominent in the right hemisphere. This is in contrast to findings from the meta-analysis by Seghezzi and colleagues (2019), who identified right-sided occipital activity as a correlate of the sense of self-agency. Increased occipital activity is however a relatively common finding in studies on brain activation during hypnosis (Vanhaudenhuyse et al., 2014; Wolf et al., 2022). The increased activation for cerebellar-parietal areas in NN is consistent with the results of Walsh et al. (2015), although it was not found for the HH.

5. Conclusions

This study evinced experiential and brain function differences between automatic writing and purposeful copying. It furthermore found similarities and differences between spontaneous and hypnotically induced automatic writing. The strengths of this project include the neurophenomenological evaluation of a rare, exceptional spontaneous automatic writer along with a comparison of her experience and related brain dynamics to those of a cohort of four hypnotic individuals able to perform AW, although not at her level of complexity. Testing AW repeatedly increased the measurement reliability of her measures.

The study has, however, various limitations, including the fact that, given the rarity of NN's level of automatic virtuosity, we could not investigate more individuals like her and establish to what extent she is representative of other spontaneous automatic writers. Our study refers to a single individual with a particular talent and a small group, although these types of comparisons have been reported in neuropsychology and clinical psychology (e.g., Crawford et al., 2003; Sedeño et al., 2014). Nonetheless, the analyses for self-reports are based on a very small *N,* and should therefore be treated with caution. In addition, it was unfeasible to create exact control tasks to NN's AW, but we think that we devised a fruitful comparison condition that had the same demands for both NN and HH. Furthermore, there was excessive head movement for NN as an effect of her vigorous AW, and conspicuous deep breathing during hypnosis blocks for the Highs, all of them possible confounds for fMRI data, although we controlled statistically for movement parameters. Our procedure did not allow us to distinguish between nuances of automaticity such as sense of agency and control, which would require a different set of procedures. Finally, the neurological contrast between NN and the HH is mostly descriptive and should be replicated in the future with a design geared for inferential analyses.

Despite these limitations, the replication of previous findings from research on automaticity supports the validity of our procedure, particularly the observations on the role of premotor cortex, SMA, DLPFC and anterior insula in self-agency and of the TPJ in non-agency. fMRI results in our study not previously found should be replicated with exceptional automatic writers and/or high hypnotizables. We also showed the feasibility of hypnotic induction of automatism and that its neural dynamics were partly similar to those of spontaneous automatism. The differences may be explained by the hypnotic state effecting neural alterations that may not be present in spontaneous automatism. It is worth mentioning that although NN does not engage in self-hypnosis during AW as far as she reported and we observed, the fact that she scored as a very high hypnotizable raises the possibility that she might use hypnotic or similar strategies at the beginning of her AW, although we saw no evidence of it and she can write automatically while maintaining an ordinary conversation. Our study is but a first step in the systematic study of very complex automatisms, which deserve greater scientific scrutiny.

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CRediT authorship contribution statement

Etzel Cardeña: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization. **Lena Lindström:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Visualization. **Philippe Goldin:** Formal analysis, Methodology. **Danielle van Westen:** Data curation, Formal analysis. **Johan Mårtensson:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A. Hypnotic induction and suggestions

Just take a nice, long deep breath and start relaxing. Just pay close attention to my words and let happen whatever you feel is going to take place… If your mind wanders bring your thoughts back to my words, and you can easily experience more of what it is like to be hypnotized.

Take another deep breath, take it easy, and just let yourself relax. Relaxing more and more. And as you think of relaxing, your muscles start to relax. Starting with your right foot, relax the muscles of your right leg… Now the muscles of your left leg… Just relaxing all over. Relax your right hand, forearm, upper arm, and shoulder… Now your left hand, forearm, upper arm and shoulder… Relax your chest, neck, and muscles of your face… More and more relaxed… completely relaxed, completely relaxed….

You now feel very relaxed, but you are going to become even more relaxed. You feel pleasantly hypnotized, as you continue to listen to my voice. Now to help you go deeper into hypnosis, I will begin to count from one to twenty. As I count you will feel yourself going down farther and farther into a deep hypnotic state, in which you will experience easily the things I tell you to experience… One, you are going down into a hypnotic state… Two, down into a deep hypnotic state… Three, four, more and more hypnotized… Five, six seven… you are sinking into a deep state. I would like you to hold your thoughts on my voice and those things I tell you think of. You are finding it easier to listen to the things I tell you… Eight, nine, ten, halfway there, always more deeply hypnotized… Eleven, twelve, thirteen, fourteen, fifteen. Although deeply hypnotized you can hear me clearly. You will always hear me distinctly no matter how hypnotized you feel yourself to be. Sixteen, seventeen, eighteen, always more deeply hypnotized. You are going to experience may things that I will tell you to experience. Nineteen and twenty! Deeply hypnotized, you will wish to have the experiences I will describe to you….

State?

Now, concentrate on your right (left) hand. Start moving it up and down gently from the wrist. Keep moving the hand up and down without stopping, with small movements … You will notice soon that the movement becomes more and more automatic and that the hand starts moving on its own, more and more automatically, without your needing to do anything… Your muscles will not get tired but the opposite, they will become more and more active… Notice how the movement becomes more and more automatic, as if the hand had a mind of its own… The hand is becoming more and more active, more and more automatic… Continue the movements in your hand as you are feeling even more hypnotized. *Now open your eyes, if you have them closed, while remaining deeply hypnotized and let your hand hold the pencil on top of the paper, ready to move.*

State?

Now notice that your hand feels like writing letters, or patterns or shapes on the paper on its own and starts to move without your having to do anything. Your hand moves with increasing ease. You do not need to control or plan what your hand will do, just let it move up and down, up and down, side to side, making shapes or symbols or letters on the paper with greater and greater ease. The movement is automatic, happening on its own. Once it starts, it becomes easier and easier to let your hand and arm move automatically, easier and easier. Just allow your hand to continue writing automatically until I tell you to stop, without it getting tired or strained… *It is important that you keep your eyes open all the time while your hand writes.*

Dehypnosis.

Your arm can stop moving now. To save time in the future, I am going to give you a cue so that you will be able to enter a state of hypnosis in a few seconds. This will be important because we will be able to spend more time on other tasks. Now listen carefully, each time I say "go into hypnosis" and you are willing, you will go right back to a deep, hypnotic state.

For now, concentrate on my voice and, as you do so, start coming out of hypnosis, becoming more and more aware of your surroundings and the ordinary control of your hand and arm. In a moment, I will count to 3. When I reach 3, you will have come out of hypnosis, you will feel fully alert and with a deep sense of well-being ….

1. You are becoming more and more awake and alert, with a normal sense throughout your whole body, including your hands and arms. 2. You are coming out of hypnosis, you sense your surrounding and your whole body feels normal. 3. You are out of hypnosis and feel wide alert and feel very fine. How are you feeling?

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bandc.2023.106060.

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