Body Structural Representation in Schizotypy

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Abstract

A deficient sense of self, typically observed in schizophrenia spectrum disorders, is often accompanied by abnormalities in bodily perception and awareness. These abnormalities are seemingly among the most powerful predictive factors for the onset of schizophrenic illnesses. According to the hypothesis of the psychosis continuum, high schizotypal traits in the general population may be characterized by a progressive sense of detachment from one's lived body. Building upon previous research that found an abnormal Body Structural Representation (BSR) in individuals with schizophrenia, this study aims to extend these findings to schizotypy. To investigate this, we utilized the Finger Localization Task (FLT), in which participants must identify the finger touched by the experimenter, and the In Between Task (IBT), in which two fingers are touched and participants must specify the number of fingers in between the two stimulated fingers. We found that individuals with high schizotypy were significantly less accurate than individuals with low schizotypy in determining the spatial configuration of their own fingers relative to each other. Most significantly, performances on both tasks were negatively correlated with the score on the Dissociative Experiences Scale (DES). These findings support the hypothesis that the progressive loss of one's sense of self is associated with abnormal bodily experiences and dissociative symptomatology which may represent a potential marker for schizophrenia proneness.

Keywords

Schizotypy; Embodiment; Selfhood; Dissociative symptoms.

1. Introduction

Schizophrenia spectrum disorders are characterized by a complex profile of symptomatology. The core feature of the spectrum appears to be characterized by abnormalities of fundamental selfhood, sometimes termed ‘ipseity’ or the ‘minimal self’ (Nordgaard & Parnass, 2014; Gallagher 2004). The minimal self could be described as a pre-reflective sense of awareness that one is an autonomous agent who ‘owns’ their experiences. The minimal self can be contrasted with the narrative or descriptive self, which involves autobiographical information or an explicit concept about one’s individual identity. Thus, even if the narrative or descriptive self is impaired (as may occur in amnesia), the minimal self should remain intact provided that the individual retains a pre-reflective sense of agency and body ownership. Phenomenologically-oriented neuroscientists have posited that one’s body provides a tacit, “background” sense of one’s first-person presence and fundamentally grounds their relationship to the environment (Uhlhaas & Mishara, 2007; Gallese & Ferri, 2013; Petitmengin et al., 2019). Thus, pre-reflective forms of selfhood are likely rooted in a bodily context, as the body represents a “minimal threshold” component of selfhood, which does not require explicit conceptualization to profoundly influence the agent’s cognition (de Haan & Fuchs 2010).

Research has afforded significant attention to various clinical manifestations of embodiment and selfhood, particularly insofar as such body perception related measures improve the early detection of, and provide preventive measures for, schizophrenia. Indeed, several studies have found that an anomalous sense of body ownership (Peled 2000 and 2003, Thakkar et al., 2011, Ferri et al., 2014; Ferri et al., 2020), aberration in body image (Priebe & Rohricht, 2001; Ferri et al., 2012), disintegration of bodily boundaries (Parnas et al., 2003; Noel., 2016; Di Cosmo, 2018), abnormal sensorimotor representation of body parts (Ardizzi, 2020), altered self-recognition (Sandsten et al., 2020; Pan & Zhou, 2020), blurred boundaries (Ferroni et al., 2019), and perceived changes in the shape and location of body parts (Priebe & Röhricht, 2001) are common features of schizophrenia spectrum disorders. In particular, it has been observed that abnormalities in the sense of embodiment, such as loss of contact with one’s own body and the disintegration of bodily boundaries, actually manifest prior to the first symptoms typically used to establish a diagnosis (Szczotka & Majchrowicz, 2018; Maggini & Raballo, 2004; de Haan & Fuchs, 2010) and persist during the course of the disorder (Nelson et al., 2012). Thus, these abnormalities in embodiment and corporeality are observable in those who merely carry a liability for schizophrenia (e.g., schizotypes), significantly before the onset of the first psychosis symptoms occur (Handest & Parnas, 2005). Correspondingly, the symptomatology observed in schizophrenia spectrum disorders may be a consequence of more malleable models of body representation (Graham-Schmidt et al., 2016) and of an earlier loss of contact with one's own body (Huber, 1957; Stanghellini et al., 2012)

The development of a coherent sense of self can be considered as a process that requires the retention of various body representations. Most prominent of these include 'body schema' and 'body image'. However, there has been confusion surrounding the distinction between these two concepts (Gallagher & Zahavi 2012). To clarify, body *image* is an explicit attitude or perception directed towards one's own body, whereas the body *schema* constitutes a set of largely automatic task-related, bodily-motor orientations. While my body itself is the intentional-object in the body image (how my body looks or feels *to* me), the environment is the intentional-object in the body schema (how I use my body to engage in various actions) (Merleau-Ponty, 1945; Gallagher and Zahavi 2012). This distinction echoes the phenomenological division between the body-as-object or "Korper" (i.e. the physical body "I" that is observable both by myself and by others), and the body-as-subject or "Leib" (i.e. the body "I" pre-reflectively experience as a subject) (Merleau-Ponty, 1945).

One emerging yet understudied example of a body representation is the Bodily Structural Representation (BSR). BSR denotes the agent's topological model of how their various body parts relate to one another in a spatial configuration (Longo, 2016). A functional bodily structural representation likely allows the individual to properly explore their own body (body image) and to use their body as an interface for engaging with the world (body schema) in a properly co-ordinated fashion. Impairments in the BSR are often localized to the fingers, such as in finger agnosia (patients who are unable to identify their digits) (Kinsbourne & Warrington, 1962). Those with severe BSR impairments cannot point to their body parts on command nor judge the spatial relationships between body parts, such as in the condition of autotopagnosia (Longo, 2016).

A recent study has found that schizophrenic patients show impairments in the Finger Localization Task, a task designed to detect abnormalities in the BSR (Costantini et al., 2020). The authors found that BSR abnormalities were correlated with deficits in body ownership, as indicated by higher susceptibility to the Rubber Hand Illusion, and to basic symptoms (i.e. a set of mild self-experienced subclinical disturbances that are present since the prodromal phase; Schultze-Lutter, 2009). Moreover, evidence supporting a deficient BSR in schizophrenia has recently been observed by Graham-Smith et al., (2016). The authors found that patients with schizophrenia performed poorly in the In Between Task, a task in which a correct performance relies on an intact BSR of the hand and more particularly the fingers. This deficit in BSR could be conceptualized in terms of a weakened internal modelling of the self or an excessive plasticity of its boundaries and spatial configuration. This is consistent with observations that the sense of self generally is either deteriorated or more malleable in people with schizophrenia spectrum disorders (Thakkar et al., 2011) and that this deterioration or malleability includes pre-reflective experiences of embodiment (Parnas, 2013; Fuchs, 2005; Ferri et al., 2012).

This breakdown in bodily self-experience implies a loss of the implicit gestalt structure of the body, or of “transparency of experience” (Sass & Parnas, 2000). This is manifested through the agent’s inability to switch between the first-person perspective (i.e. the subjective body) and the third person perspective (i.e. the objective body) (Sass, 2003; Krueger, 2018). A similar pattern of bodily self-dissociation also been observed in dissociative disorders (e.g. dissociative identity disorder, depersonalization and derealization). Dissociative disorders are characterized by a disruption in the regular ability to switch between first-person and third-person perspectives and by a reduced sense of being in touch with the world (Ciaunica et al., 2020). Similarly, schizophrenic individuals experience a disintegration at the minimal level of subjectivity, which is normally implicit throughout all of one’s experiences. In both conditions, the subject may feel profoundly detached from the medium (i.e., the body) that usually ‘anchors’ them to their environment, leading to a sense of alienation from both their surrounding environment as well from their typical experience of selfhood.

Unsurprisingly, then, research has suggested a possible overlap between schizophrenia spectrum disorders and dissociative disorders (Moise et al., 1996; Ross and Keyes, 2004). For instance, dissociative symptoms are often found in first-episode psychotic patients (FEP) (Sun et al., 2019), and in individuals with schizotypal personality disorder (Watson, 2001; Giesbrecht & Merckelbach, 2008; Pope & Kwapil 2000). The potential link between dissociation and schizophrenia provides a useful resource for understanding schizophrenia spectrum disorders, particularly if we assume that the fracture between the observing and the observed self represents a hallmark for the emergence of the disorder.

The aim of the present study was to broaden previous findings by investigating the Body Structural Representation in individuals with high and low schizotypy. For this purpose, we utilized the Finger Localization Task (FLT) (Benton et al., 1983), in which participants have to identify which of their fingers is being touched by the experimenter, and the In Between Task (IBT) (Kinsbourn & Warrington, 1962), in which two fingers of the same hand are touched and the participants must count the number of fingers in between the two stimulated ones. Both tasks assess fine-grained acuity in body mapping (Kinsbourn & Warrington, 1962; Benton et al., 1983; Graham-Smith et al., 2016) and have been utilized to investigate Body Structural Representation in schizophrenic individuals (Graham-Smith et al., 2016; Costantini et al., 2020).

Our hypothesis was that individuals with high schizotypy, as assessed by the Schizotypal Personality Questionnaire (SPQ), would display less accuracy in BSR-related tasks than people with low schizotypy. This hypothesis is in-keeping with the continuum hypothesis which posits that characteristic symptoms of schizophrenia are present in less severe forms in individuals with high schizotypy (DeRosse & Karlsgodt, 2015; Kwapil & Barrantes-Vidal, 2015; Nelson et al., 2013). Moreover, grounding on prior research that observed an overlap between dissociation and schizophrenia (Ross, 1997; 2009), we asked participants to complete a questionnaire designed to measure dissociative experiences: the Dissociative Experiences Scale (DES). We predicted that reduced performance accuracy in the tasks would be associated with higher scores in the SPQ and the DES.

2.Materials and Methods

2.1. Participants

Two hundred sixty-eight students, recruited via mailing lists at the University of Essex, were screened with respect to schizotypal personality traits using the Schizotypal Personality Questionnaire (SPQ; Raine, 1991). The distribution of scores was divided into quintiles, with the first quintile representing the participants rated as low schizotypes and the fifth quintile representing the participants rated as high schizotypes. Based on their scores, 55 participants in total (27 low schizotypes and 28 high schizotypes) were called to complete the full study. Participants gave written consent before taking part in the experiment and all were naïve to the actual purpose of the study. All participants were right-handed. The sample size estimation was based on previous studies investigating tactile confusions of the fingers (Manser-Smith et al., 2018; Cicmil et al., 2016).

2.2. Questionnaires

2.2.1. Schizotypal Personality Questionnaire (SPQ)

Schizotypal personality traits were assessed using the Schizotypal Personality Questionnaire (SPQ) (Raine, 1991). The SPQ is a 74 items' questionnaire that has been modelled after the DSM-III-R schizotypal personality disorder diagnostic criteria (Venables & Raine, 2015). The questionnaire assesses three well-replicated factors of schizotypy: cognitive-perceptual deficits, interpersonal deficits, and disorganization. This factor structure of the SPQ corresponds to the three cluster symptoms observed in people with schizophrenia (DSM-V, 2014): positive symptoms (i.e. cognitive-perceptual symptoms such as hallucinations and delusions), negative symptoms (i.e. interpersonal symptoms such as apathy and social avoidance) and disorganized symptoms (i.e. disorganization symptoms such as abnormal speech and behaviour).

2.2.2 Dissociative Experiences Scale (DES)

On the day of the experiment, participants were asked to complete the Dissociative Experiences Scale (DES) (Bernstein & Putnam, 1986). The Dissociative Experiences Scale (DES) is a widely used instrument in both clinical and nonclinical samples. The scale consists of 28 items assessing the frequency and the severity of a series of dissociative experiences. Participants were asked to determine to what extent the experiences described would apply to them by using an eleven-point visual analog scale (0%–100%) (Mazzotti et al., 2016). The DES assesses different aspects of dissociation: absorption (e.g. experiences of detachment with the immediate surroundings and with the present moment); depersonalization (e.g. feelings of disconnection from one's identity and body, such as out-of-body experiences); derealization (e.g. feelings of alienation from the outside world which is perceived as unreal and not recognizable – i.e. objects perceived as altered, individuals perceived as inanimate); dissociative amnesia (i.e. failure into retrieving personal information that would normally be accessible) (Waller et al., 1998). Factor analyses have shown that a three-factor model best account for clinical samples (Ross et al., 1995), whereas one-factor best account for nonclinical samples (Holtgraves & Stockdale, 1997), indicating that overall score is the most reliable measure for the purpose of the current study where we investigated sub-clinical samples. Research has suggested that scores above 30 are highly indicative of a severe dissociative pathology and scores above 40 are highly indicative of Dissociative Personality Disorder (Carlson & Putnam, 1993).

2.3. Behavioral tasks

2.3.1. Finger Localization Test

Participants sat in front of a table with a box, which served to hide the participant's hands, and a drawing (outline) of a human hand. In the outline drawing, the fingers of each hand were given a number (see figure 1) that participants could use to identify the corresponding finger on their own hand. Participants were asked to put their hands on the table, with their palms facing upwards and their fingers stretched and slightly separated. Participants provided their responses by naming the fingers that were stroked referring to the outline drawing of a hand with numbered fingers. Responses were recorded with pen and paper. The test consisted of three tasks (ten trials on each hand per task). The first task required participants to identify the finger of the left or the right hand touched by the experimenter (figure 1a). The second task required participants to identify the finger of the left or the right hand touched by the experimenter, with the hands hidden from view (figure 1b). Finally, the third task required participants to identify pairs of fingers of the left or the right hand touched by the experimenter with the hand hidden from view (figure 1c). In the third task, responses were counted as correct when both fingers were accurately identified.

Figure 1 near here

2.3.2. In-between test

The in-between test has been widely used in research to investigate body structural representation of the hand in neurological patients (Kinsbourn & Warrington, 1962). The test has had various adaptations in different research assessing body structural representation in also healthy participants and the cortical areas involved (Rusconi et al., 2014). Here, we utilized a variation of the original task by Kinsbourn & Warrington, (1962).

Participants sat in front of a table with their hands resting on the table and their palms up, finger slightly spread, eyes closed. The experimenter simultaneously stroked two fingers on the participant's hand, making sure to apply the same pressure for approximately one second (Graham-Smith et al., 2014). Participants were asked to make unspeeded verbal responses as to how many fingers they felt were between the fingers that were touched (See figure 2). Responses were manually documented by the experimenter. The procedure was repeated 10 times for each hand. The order of the trials was established in a pseudo-random manner before the test began, following a pre-established combination. The combination in which no fingers was in between on either hand ("0" answer) was presented twice; one finger in between (“1” answer) was presented three times; two fingers in between (“2” answer) was presented twice and three fingers in between (“3” answer) was presented three times. This particular adaptation was adopted as a variation of the original task (Kinsbourn & Warrington, 1962), which was considered too simplistic to assess performance in healthy individuals without any known neurological condition.

Figure 2 near here

3. Data Analysis

3.1 Finger Localization Test

3.1.1 Accuracy and correlation with DES

The accuracy on each task (A, B and C) was determined by the summation of correct responses for each hand. The maximum accuracy for each task was 20. Nonparametric analyses were performed to test for between-group differences in the number of correct responses for the right and the left hand. Finally, we performed correlation analyses between DES total score and accuracy in the finger localization test for all participants.

3.1.2 Confusion Matrix for pairs and single digits

A confusion matrix shows the pattern of mislocalisations of tactile stimuli on the digits (see Manser-Smith et al., 2019). As for task C, for each group of participants we first computed a confusion matrix showing the proportion of correct localisations and the pattern of mislocalisations on pairs of digits as a function of which digits were stimulated. Then, we computed a confusion matrix showing the proportion of stimuli judged as located on each of the five digits as a function of which digit was stimulated. To compute these values, we referred to single fingers being stimulated (e.g stimulation 3:4 was considered twice, one for finger 3 and one for finger 4). Non-parametric analyses were performed on the proportion of correct responses for each digit, shown along the diagonal of the confusion matrix, to test for differences in accuracy between high and low schizotypes for each stimulated digit.

3.1.3 Directionality Index

To obtain a single value which shows both direction and magnitude of bias in finger selection, we computed the directionality index (DI) developed by Cicmil et al., (2016). Responses were analysed for both the right and the left hand. The DI was obtained by calculating the mean of the identification number (ID) values given in response to stimulation and subtracting from the digit's ID number:

DI = (mean of the response ID numbers – stimulated finger's ID number). The DI shows the directionality of the identification errors given in response to the tactile stimulation of the finger: it reveals whether erroneous identification responses are predominantly biased toward the medial direction ($DI < 0$) or lateral direction ($DI > 0$), or unbiased ($DI = 0$). Finally, we tested for differences in DI between high and low schizotypes, and for each stimulated digit.

3.2 In-Between Test

3.2.1 Accuracy and correlation with DES

The accuracy was determined by the proportion of correct fingers in-between responses. Nonparametric analyses were performed to test for between-group differences in the number of correct responses for the right and the left hand. Finally, we performed correlation analyses between DES total score and accuracy in the in-between test for all participants.

3.2.2 Confusion Matrix

For each group of participants, we computed a confusion matrix showing the proportion of correct responses as well as the pattern of erroneous responses when estimating how many fingers are in between the stimulated digits. Non-parametric analyses were performed on the proportion of correct responses shown along the diagonal of the confusion matrix to analyse whether there was a significant difference between high and low schizotypes in the “number of fingers in-between” responses to stimulated digit pairs.

3.2.3 Numerosity Index (NI)

The NI was obtained by calculating the mean of the finger in between values given in response to stimulation and subtracting from the actual number of digits:

NI = (mean of the of the finger in between values – actual number of digits).

The NI reveals whether erroneous numerosity responses are predominantly biased toward underestimation (NI < 0) or overestimation (NI > 0), or unbiased (NI = 0). Finally, we tested for differences in NI between high and low schizotypes and for the different fingers in-between conditions.

4. Results

4.1. Self-report measures

4.1.1. Schizotypal Personality Questionnaire

From 268 participants who initially completed the SPQ questionnaire, 55 participants in total were called to complete the full study. Based on their scores, a total of 28 participants were selected from the uppermost 20% of the scores (score range: 35- 60), representing participants rated as high schizotypes, and 27 from the lowermost 20% of the scores (score range: 2 -16), representing participants rated as low schizotypes. This sample consisted of 14 male and 41 female participants.

4.1.2. Dissociative Experiences Scale

The 28 items of the questionnaire were assessed using an eleven-point scale (0%-100%). The scores were calculated by totalling the percentage indicated by each participant for each question (from 0% to 100%) and then dividing it by 28. The scores ranged from 0 to 100 (score range: 6.4- 74). Those who scored above 30 (24 participants out of 55), were considered to have high dissociative traits. A t-test was performed to check whether the DES scores differed between participants who scored high and low in the SPQ. Mean score on the DES for participants with low SPQ scores (M = 17.4, SD = 10.8), significantly differed from mean score for participants with high SPQ scores (M = 39, SD = 17), demonstrating that individuals with higher schizotypal traits on average scored higher on the DES (t(54) = 5.635, p <.001).

4.2. Behavioral Tests

4.2.1. Finger Localization Test

4.2.1.1 Accuracy and correlation with DES

As in Costantini et al., (2020), performance in tasks A and B was at ceiling, with 96.4% of participants obtaining the maximum score in task A and 80% obtaining the maximum score in task B. Therefore, we performed accuracy analysis for task C only. Since the accuracy scores were not normally distributed (all ps < .035; Kolmogorov-Smirnov test), we performed nonparametric analyses to test for between-group differences in the number of correct responses for the right and the left hand.

A Kruskal-Wallis test performed on participants' mean accuracy averaged across the two hands revealed a main effect of group (χ2(1) = 7.71, p = .006) (figure 3a). The same test performed on the differential accuracy (right-left hand) revealed that the group by laterality interaction was not significant (χ2(1) = 2.69, p = .101). Conversely, the main effect of laterality was significant, with higher accuracy for the right than the left hand (86% vs 82%), as revealed by a Friedman test (χ2(1) = 5.45, p = .020). The effect of dissociative traits on the structural representation of the hand was analyzed using the Spearman correlation analysis. A significant negative correlation was found (rs(53) =-.32, p = .01) indicating that the higher the DES total score, the worse the individual accuracy when localising the touched fingers (figure 3b).

Figure 3 near here

4.2.1.2 Confusion matrix for pairs and single digits

The confusion matrix for pairs of stimulated digits showed different patterns of correct localisations and mislocalisations between the two groups, with high-schizotypes more variable in their responses than low schizotypes (figure 4).

Figure 4 near here

Similarly, the confusion matrix for single stimulated digits showed different patterns of correct localisations and mislocalisations between the two groups (figure 5a).

Between-group differences were confirmed by non-parametric tests performed on the proportion of correct responses for each digit, shown along the diagonal of the confusion matrix (figure 5a). Note that, according to the results from the main non-parametric analyses on accuracy, here we did not test for differences between right and left hands further. Specifically, Kruskal-Wallis test performed on participants' mean accuracy averaged across the fingers revealed a main effect of group ($\chi2(1) = 5.39$, $p = .020$), indicating that individuals with high schizotypy made more mistakes on each stimulated finger. Moreover, the main effect of finger was shown by a Friedman test ($\chi2(4) = 85.16$, $p < .001$) and Durbin-Conover pairwise comparisons revealed that proportion of correct responses were significantly lower for both the middle and ring fingers as compared to all the other fingers (all ps < .001), as well as for the index finger as compared to both the thumb and little finger (both ps < .001). Finally, to investigate the group by finger interaction, a Kruskal-Wallis test was performed contrasting the proportion of correct responses for each finger between the two groups. This analysis revealed that there was a significant between-groups difference for the index finger only ($\chi2(1) = 5.12$, $p = .024$), with high-schizotypy individuals making more mistakes. The between-groups differences only approached significance for the middle and ring fingers (respectively, $\chi2(1) = 3.52$ and 2.95, $p = .061$ and .086) (figure 5b).

Figure 5 near here

4.2.1.3 Directionality Index

The DI values were not normally distributed (all ps < .001; Kolmogorov-Smirnov test), so we performed nonparametric analyses to test for differences between high and low schizotypes, and for each stimulated digit. The group by laterality interaction was tested by a Kruskal-Wallis test performed on participants' right-left difference in DI values averaged across the fingers. The interaction was significant (χ2(1) = 5.01, p = .025), as low-schizotypy and high-schizotypy groups showed a similar response bias (towards the medial direction) for the left hand, while for the right hand only low-schizotypy individuals showed a similar bias (figure 6). Moreover, the main effect of finger was shown by a Friedman test (χ2(4) = 74.83, p < .001) and Durbin-Conover pairwise comparisons revealed that the DI values were significantly lower for both the middle and ring fingers, which showed a bias toward the midline, as compared to all the other fingers (all ps < .003); moreover, the DI values were significantly higher for the index finger, which showed a bias toward the external side, as compared to all the other fingers (all ps < .001). Finally, the laterality by finger interaction only approached statistical significance (χ2(4) = 9.20, p = .056) in a Friedman test performed on participants' right-left difference in DI values for each finger. Durbin-Conover pairwise comparisons revealed that the right-left difference in DI values was significantly higher for both the middle and ring fingers as compared to the index finger (respectively, p = .012 and .035). All the other effects did not reach statistical significance.

Figure 6 near here

4.2.2. In-Between Test

4.2.2.1 Accuracy and correlation with DES

Since the proportion of correct responses was not normally distributed (all ps < .001; Kolmogorov-Smirnov test), we performed nonparametric analyses to test for between-group differences in the proportion of correct fingers in-between responses for the right and the left hand. A Kruskal-Wallis test performed on participants' mean proportion of correct responses averaged across the two hands revealed a main effect of group (χ2(1) = 5.92, p = .015) (figure 7). The same test performed on the difference in the proportion of correct responses between right and left hands revealed that the group by laterality interaction was not significant (χ2(1) = 0.26, p = .609). Moreover, the main effect of laterality only approached the statistical significance, as shown by a Friedman test (χ2(1) = 3.20, p = .074). The effect of dissociative traits on the structural representation of the hand was analyzed using the Spearman correlation analysis. A significant negative correlation was found (rs(53)= -.35, p <.001) indicating that individuals with high dissociative traits are less accurate when asked to identify how many fingers are in between the stroked fingers (figure 7).

Figure 7 near here

4.2.2.2 Confusion matrix

As with the Finger Localization test, here we computed a confusion matrix to investigate whether there were different patterns of correct responses ("how many fingers in between") and errors between high and low schizotypy groups (figure 8a).

Between-group differences were revealed by non-parametric tests performed on the proportion of correct responses shown along the diagonal of the confusion matrix (figure 8). Note that, according to the results from the main non-parametric analyses on accuracy, here we did not test for differences between right and left hands further. Specifically, Kruskal-Wallis test performed on participants' proportion of correct response averaged across the four levels revealed a main effect of group (χ2(1) = 5.95, p = .015). Moreover, the main effect of the fingers in-between factor was confirmed by a Friedman test (χ2(3) = 58.23, p < .001) and Durbin-Conover pairwise comparisons revealed that fingers in-between values were significantly lower for level 2 as compared to all the other levels (all ps < .001), as well as for level 1 as compared to level 0 (p = .002). Finally, to investigate the group by fingers in-between interaction, a Kruskal-Wallis test was performed contrasting the fingers in-between values for each level between the two groups. This analysis revealed that there was a significant between-groups differences for both level 1 and level 2 (respectively, χ2(1) = 4.12 and 5.81, p = .042 and .016), while the between-groups differences only approached significance for level 3 (χ2(1) = 2.88, p = .090) (figure 8b).

Figure 8 near here

4.2.2.3 Numerosity Index

The NI values were not normally distributed (all ps < .001; Kolmogorov-Smirnov test), so we performed nonparametric analyses to test for differences between high and low schizotypes in the different fingers in-between conditions. The condition "fingers in-between" =0 was not included in the analysis, as no errors have been observed. A Kruskal-Wallis test performed on participants' mean NI values averaged across the three levels of the fingers in-between factor revealed a significant main effect of group (χ2(1) = 10.98, p < .001), with lower values (NI < 0) for the low schizotypy group and higher values (NI > 0) for the high schizotypy group. To investigate the group by fingers in-between interaction, a Kruskal-Wallis test was performed contrasting the NI values for each fingers in-between level between the two groups. This analysis revealed significant between-group differences for both the level 1 and level 2 of the fingers in-between factor (respectively, χ2(1) = 6.34 and 10.55, p = .012 and .001), with lower values (NI < 0) indicating a bias towards underestimation for the low-schizotypy group and higher values (NI > 0) indicating a bias towards overestimation for the high schizotypy group. Conversely, the between-group difference was not significant for the level 3 (χ2(1) < 0.01, p = .963) (figure 9). A Friedman test revealed that the main effect of fingers in-between factor was not significant (χ2(2) = 1.17, p = .558).

Figure 9 near here

5. Discussion

This study aimed to investigate the body structural representation in individuals with high and low schizotypy. To this purpose, we used two tests: the FLT and the IBT. Both tests have recently been employed for assessing BSR in individuals with schizophrenia (Costantini et al., 2020; Graham-Smith, 2014). In accordance with the idea of psychosis as a continuum (DeRosse & Karlsgodt, 2015; Kwapil & Barrantes-Vidal, 2015; Nelson et al., 2013), our findings suggest that individuals with high schizotypy, similar to schizophrenic patients, display a reduced accuracy in BSR-related tests. More specifically, our results show that individuals with high schizotypy are significantly less accurate than individuals with low schizotypy in identifying the stimulated fingers and situating them to an outline of the hand (FLT), or in determining the spatial relationship between the stimulated fingers when their eyes are closed (IBT). Moreover, our findings show that performances in both tests were negatively correlated with scores in the DES: the higher the DES score, the worse the individual accuracy. Interestingly, high schizotypy individuals were not only less accurate, but also more variable in their responses than low schizotypy individuals, as shown by the computation of the confusion matrices. Finally, the two groups showed opposite directionality and numerosity biases.

Taken together, these results contribute to the mounting evidence that suggests that abnormalities in various dimensions of corporeality and self-awareness are common, unifying features in schizophrenia spectrum disorders including their prodromal stage. In line with this hypothesis, we propose that aetiological features of schizophrenia spectrum disorders might be better understood by further explicating their shared bodily roots. In the case of Bodily Structural Representation, a functional BSR implies an understanding of the objective spatial configuration of one's body and of its place in the environment. Consequently, agents with an impaired understanding of the structure of their bodies and its specific spatial configuration may be more malleable to adopting faulty models of their body's spatial mapping and location. The lack of a coherent understanding of oneself as a structural entity in the world may be associated with deficits in the minimal self that are typically observed in the schizophrenic spectrum. As the minimal self is mediated through the body, disruptions in BSR may constitute one of several embodiment-related factors that contribute to well-documented disturbances in minimal selfhood and the confusion between first and third person perspectives present in schizophrenia spectrum disorders.

Interestingly, research observed that schizophrenic patients display a tendency to disengage from normal forms of involvement with the external world, particularly with such acts that would normally be tacit ("in the background") and transparent. For instance, some patients report becoming excessively aware of the act of breathing or the movements of their arms while walking (Nelson & Sass, 2016). These sensations often concern the domain of pre-reflective bodily experience, whereby the body is no longer experienced as tacitly given in the first-person perspective, but it rather loses its transparent quality and becomes an overt object of observation and concern (Irrazàval, 2015). This loss of the transparent, pre-reflective sense of one's embodiment ultimately affects the capacity to switch between the body-as-subject (body schema) and the body-as-object (body image) dimensions of embodied experience, producing a fracture between the observing and the observed self (Sass, 2003). Consequently, one could feel as if they are observing their own experiences in third person, rather than from a first-person perspective. This tendency has been also referred to as "hyperreflexivity", i.e. where bodily processes that are otherwise typically unnoticed instead become intensified in reflective consciousness. It has been hypothesized elsewhere that hyperreflective dimensions of self-consciousness might stem from disturbances in the minimal self (Sass 2013; Fuchs, 2005).

Interestingly, similar experiences of self-detachment (i.e., a fracture between the observing and the observed self) are predominant characteristics of dissociative disorders (Ciaunica, 2020). Research has found that dissociative symptoms often overlap with schizophrenic symptoms (Haugen & Castillo, 1999; Putnam et al., 1986) and with schizotypal personality traits (Pope and Kwapil, 2000; Merckelbach et al., 2000; Watson, 2001). In particular, a study by Watson (2001), found that the features that contribute most strongly to this relationship pertain to symptomatology concerning detachment and depersonalization, constructs that are deeply related with changes in the quality of embodied, pre-reflective experiences. These experiences include sensations of estrangements from one's self, body, body parts, or one's surroundings (Ciaunica et al., 2020). However, individuals with dissociative identity disorders are usually aware that these are subjective and temporary phenomena, rather than an ‘objective’ reality (Ciaunica et al., 2020). It could be hypothesized then, that their ‘minimal selfhood’ is preserved. On this basis, future research could investigate which processes could represent distinguishing clinical factors between dissociative identity disorders and schizophrenia spectrum disorders. We propose that greater focus on the early detection of minimal selfhood disruptions and body abnormalities in dissociative symptomatology and schizophrenic spectrum conditions could provide useful insights in regard to this facet.

In conclusion, our results suggest that an abnormal BSR represents a potential early marker of schizophrenia. Indeed, abnormalities in BSR contribute toward observed anomalies in related body representations (e.g. body schema), which, collectively, may contribute to the development of a deficient sense of self. Evidence of a deficient BSR in both clinical and sub-clinical populations may further illuminate the nature of disordered self-experiences that are predictive of schizophrenia onset. Further research could investigate to what extent deficits in the BSR extend to other parts of the body. Furthermore, it may also be productive to investigate the difference between deficits in body structural representation and other deficits in spatial processing and representation. In addition, the results from the present paper provide further insights regarding the relationship between schizophrenia spectrum conditions and dissociation. Interestingly, prior research found that both dissociation and schizophrenia spectrum disorders are often associated with a history of trauma (Allen & Coyne, 1995). This relationship might be linked to the fact that post-traumatic intrusions foster abnormal perception, temporality deformation, dysfunctional reality testing abilities and bodily sensations, and may ultimately induce changes in the overall texture and quality of experience and contribute to the development of dissociative experiences (Morrison et al., 2003). Subsequent research might focus on the interrelationship between body abnormalities in schizophrenia spectrum disorders, the history of trauma and dissociation. This may further clarify the link between self-disturbances and schizophrenic spectrum conditions and help to identify suitable strategies for early intervention.

6. Limitations

Some limitations of this study should be mentioned. First, the gender sample is not balanced, mainly due to the difficulty in recruiting participants in the lower and the upper schizotypal continuum. Generally, research relating to gender effects on tactile perception reveal that women have better tactile spatial acuity than men (Woodward, 1993; Venakatesan et al., 2014). However, not much is known on the difference in body structural representation between females and males. Previous research in the In Between Task (Graham-Schmidt et al., 2016; Tamè et al., 2017) and in the Finger Localization task in normal participants (Manser-Smith et al., 2018; Cicmil et al., 2016) and in people with finger agnosia (for the Finger Localization Task) (Benton et al., 1994; De Agostini & Dellatolas, 2001), reported no relationship between performance and gender. Thus, although we believe that our lack of gender-based sample has not influenced the study results, we believe that future research should implement new tasks to further investigate body representation in males and females.

Second, when testing for the relationship between DES and task performance, we have conducted a correlation on the entire sample which was previously divided into two groups based on their SPQ scores. Thus, as there is evidence that points to a partial overlap between schizotypal and dissociative traits, especially in terms of bodily self processing (Giesbrecht & Merckelbach, 2008; Pope & Kwapil 2000; Watson, 2001) the results we found could have been an indirect effect of schizotypy. However, determining the relative contribution of schizotypy and dissociative traits, as well as of their interaction, to the participants' performance at the finger localization and the fingers in between tasks was beyond the scope of our study.

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Figure captions

Figure 1. Experimental conditions of the Finger localization task. Participants had to identify the finger touched by the experimenter, with the hands visible (a) or hidden (b) from view. In a third condition they had to identify pairs of fingers touched by the experimenter, with the hand hidden from view (c).

Figure 2. Participants kept their eyes closed. Experimenter stroked two fingers of the same hand. Participants had to verbally report how many fingers they felt were between the fingers that were stroked. There was one block of 20 trials per hand (40 trials in total). The combination in which there were no fingers in between on either hand (answer "0") was presented twice; one finger in between (answer "1") was presented three times; two fingers in between (answer "2") was presented twice and three fingers in between (answer "3") was presented three times.

Figure 3. Panel a) Mean accuracy in the finger localization task in both high and low schizotypes. Values correspond to task condition "c" ("hands hidden"). Panel b). Correlation between DES total score and accuracy in the in the finger localization task for all participants. Participants are colour-coded according to whether they were from the low or high schizotypy group.

Figure 4. Confusion matrices, in low or high schizotypes, showing the proportion of stimuli judged as located on each pair of fingers as a function of which digits were actually stimulated. Proportion of correct responses for each pair is shown along the diagonal from the top-left to the bottom-right. Mislocalizations between digits is shown in the off-diagonal cells.

Figure 5. Panel a) Confusion matrices, in low or high schizotypes, showing the proportion of stimuli judged as located on each of the five digits as a function of which digit was actually stimulated. Proportion of correct responses for each digit is shown along the diagonal from the top-left to the bottom-right. Incorrect judgments are shown in the off-diagonal cells. Panel b) Mean accuracy in the finger localization task, in low or high schizotypes, plotted as a function of each finger. Error bras indicate standard errors. * indicates $p<0.05$. + indicates p values approaching significance ($p< 0.1$).

Figure 6. Directionality index scores, averaged across the fingers, in low or high schizotypes. Error bars represent the standard error of the mean. * indicates $p < 0.05$.

Figure 7. Panel a) Mean accuracy in the in-between task in low and high schizotypes. Panel b) Correlation between DES total score and accuracy in the in-between task for all the participants. Participants are colour-coded according to whether they were from the low or high schizotypy group.

Figure 8. Panel a) Confusion matrices, in low and high schizotypes, showing the number of fingers judged in-between as a function of the real number of fingers in-between. Proportion of correct responses for each condition is shown along the diagonal from the top-left to the bottom-right. Incorrect judgments are shown in the off-diagonal cells. Panel b) Mean accuracy in the in-between

task, in low or high schizotypes, plotted as a function of the real number of fingers in-between. Error bars indicate standard errors. * indicates $p<0.05$.

Figure 9. Numerosity index scores in low or high schizotypes. The NI reveals whether erroneous numerosity responses are predominantly biased toward underestimation ($NI < 0$) or overestimation ($NI > 0$), or unbiased ($NI = 0$). Error bars represent the standard error of the mean. * indicates $p < 0.05$.

Figure 1

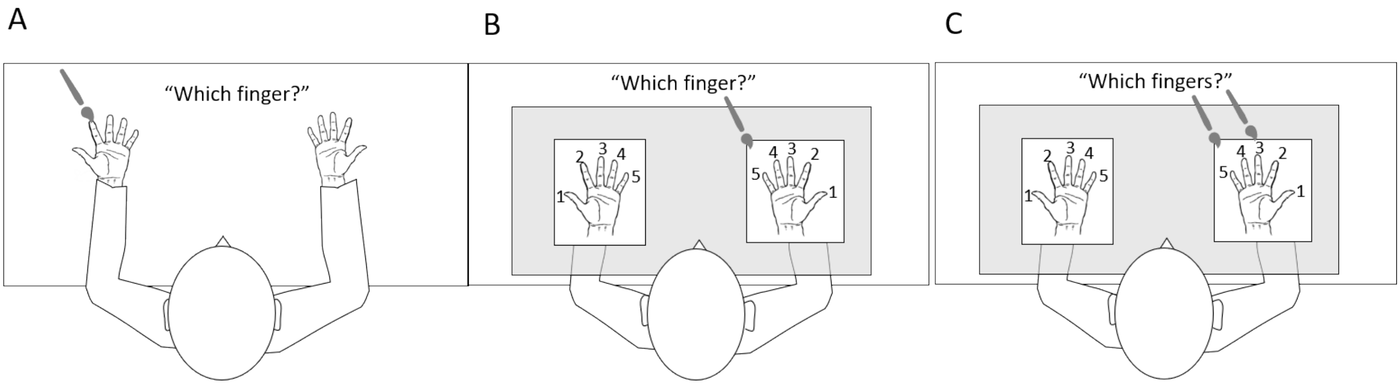

A
"Which finger?"
B
"Which finger?"
2 3 4 5 1
4 3 2 5 1
C
"Which fingers?"
2 3 4 5 1
4 3 2 5 1

Figure 2

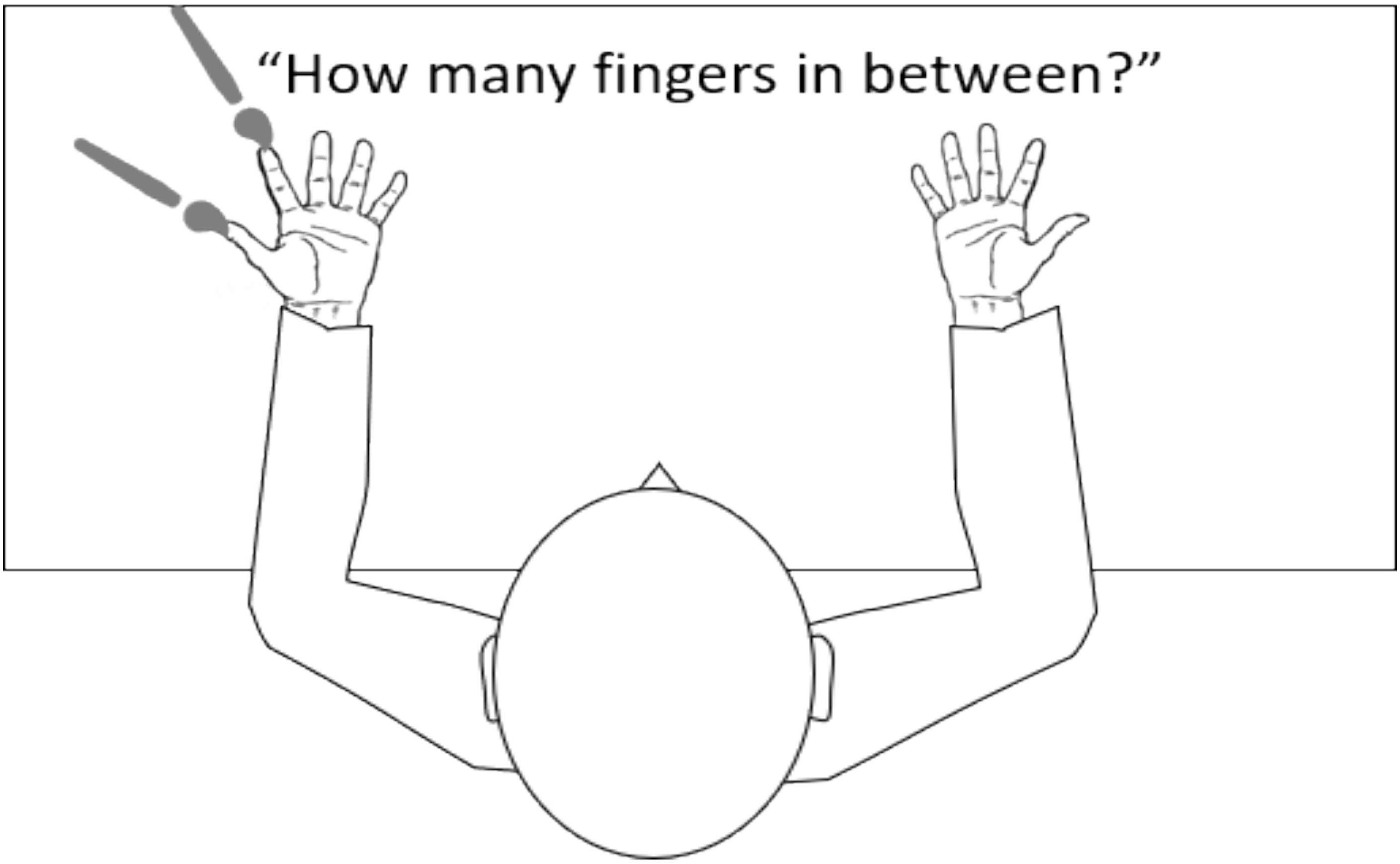
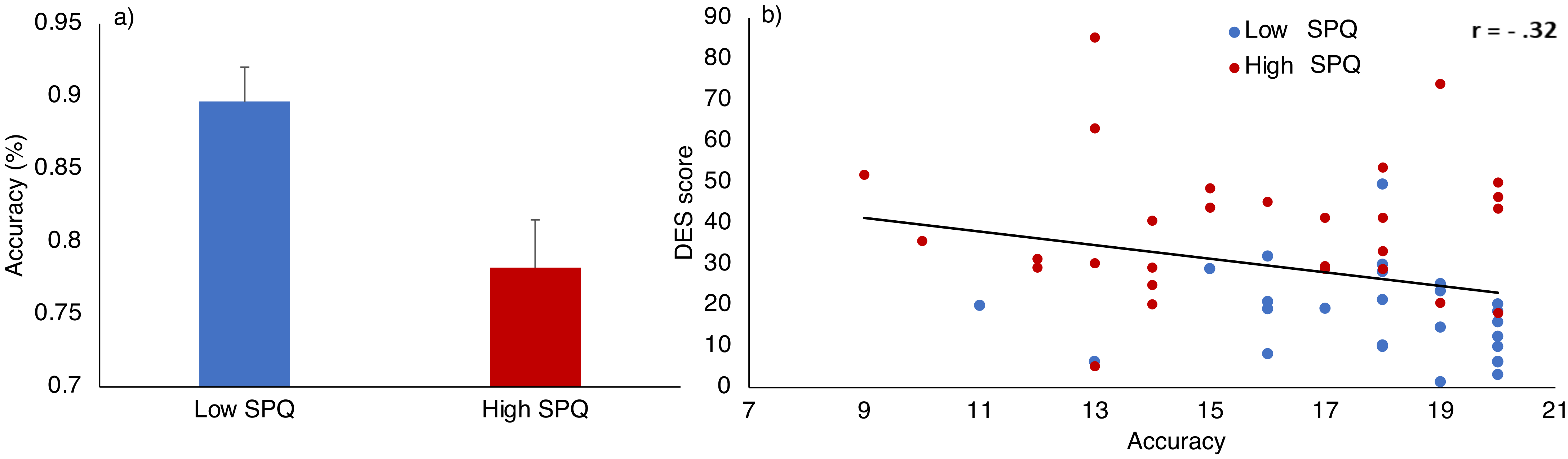
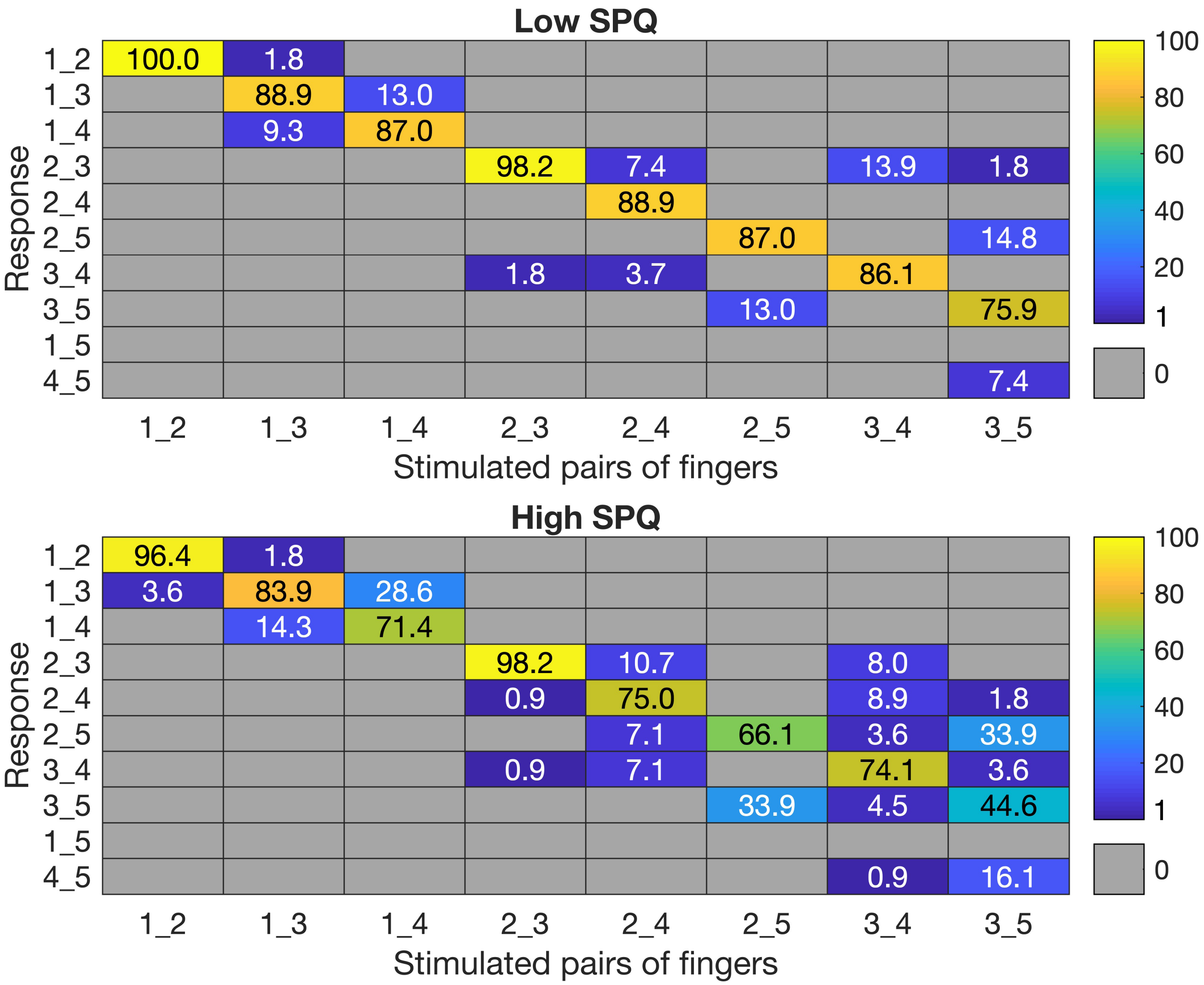


Figure 3



a)
Accuracy (%)
0.95
0.9
0.85
0.8
0.75
0.7
Low SPQ
High SPQ
b)
DES score
90
80
70
60
50
40
30
20
10
0
7
9
11
13
15
17
19
21
Accuracy
● Low SPQ
● High SPQ
r = - .32

Figure 4



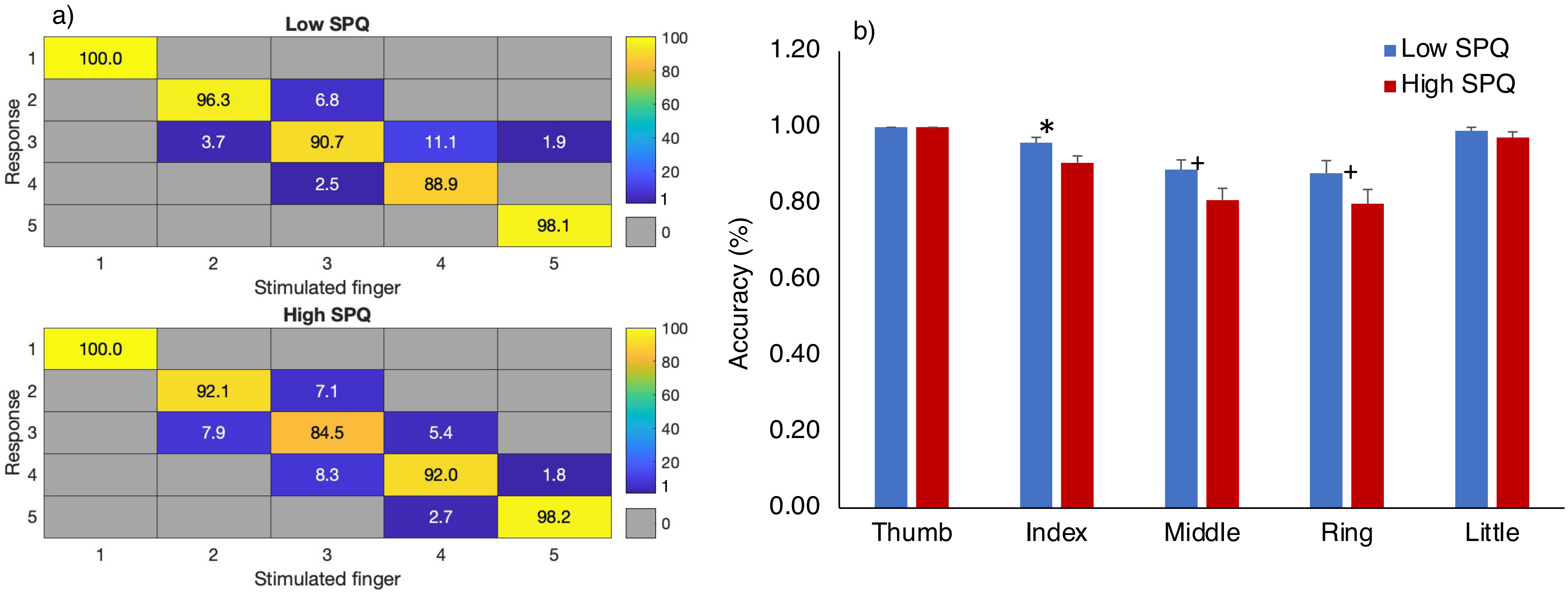
Low SPQ

Response	1_2	1_3	1_4	2_3	2_4	2_5	3_4	3_5
1_2	100.0	1.8						
1_3		88.9	13.0					
1_4		9.3	87.0					
2_3				98.2	7.4		13.9	1.8
2_4					88.9			
2_5						87.0		14.8
3_4				1.8	3.7		86.1	
3_5						13.0		75.9
1_5								
4_5								7.4

High SPQ

Response	1_2	1_3	1_4	2_3	2_4	2_5	3_4	3_5
1_2	96.4	1.8						
1_3	3.6	83.9	28.6					
1_4		14.3	71.4					
2_3				98.2	10.7		8.0	
2_4				0.9	75.0		8.9	1.8
2_5					7.1	66.1	3.6	33.9
3_4				0.9	7.1		74.1	3.6
3_5						33.9	4.5	44.6
1_5								
4_5							0.9	16.1

Figure 5



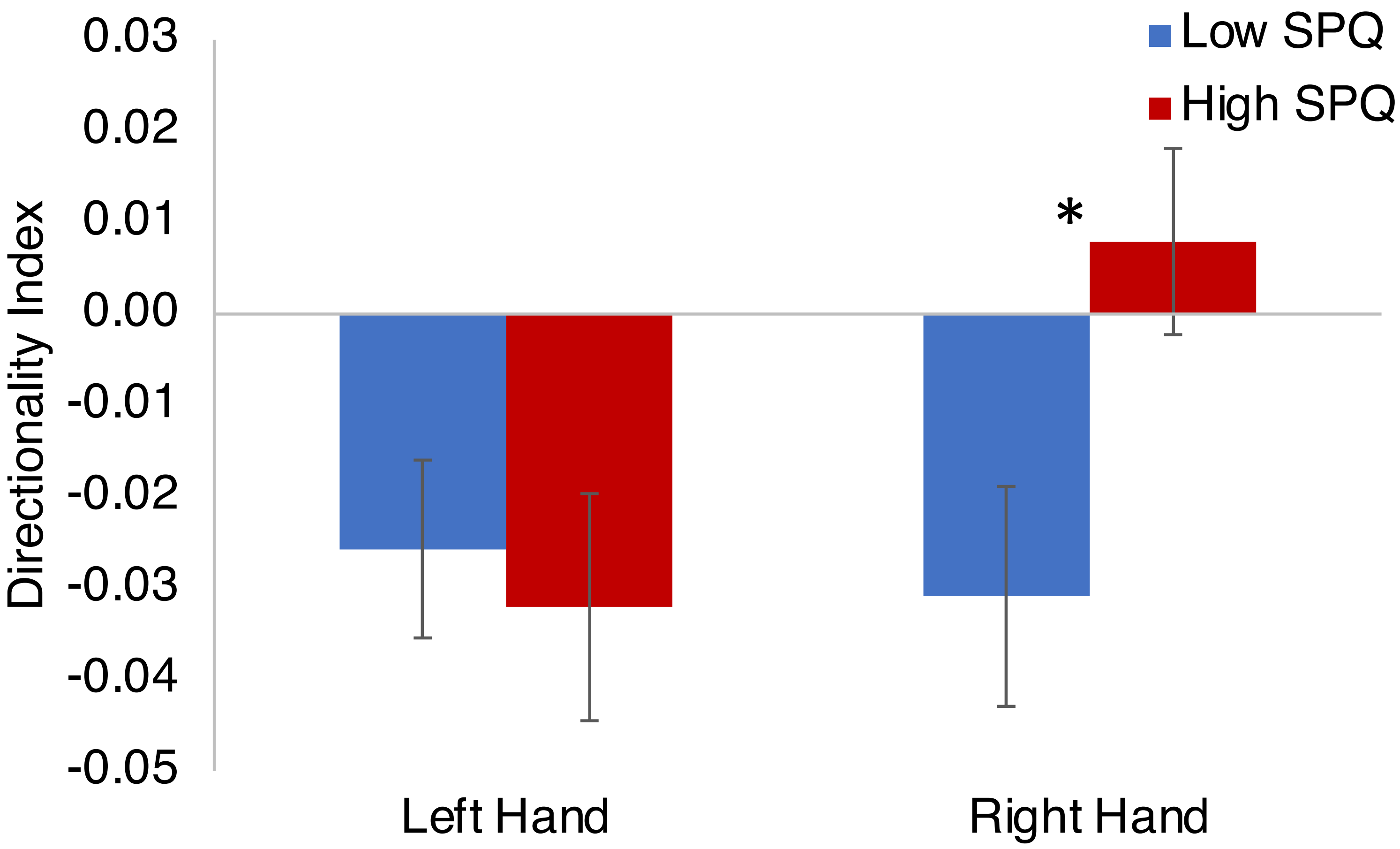
Low SPQ

	1	2	3	4	5
1	100.0				
2		96.3	6.8		
3		3.7	90.7	11.1	1.9
4			2.5	88.9	
5					98.1

High SPQ

	1	2	3	4	5
1	100.0				
2		92.1	7.1		
3		7.9	84.5	5.4	
4			8.3	92.0	1.8
5				2.7	98.2

Figure 6



Low SPQ
High SPQ
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
Directionality Index
*
Left Hand
Right Hand

Figure 7

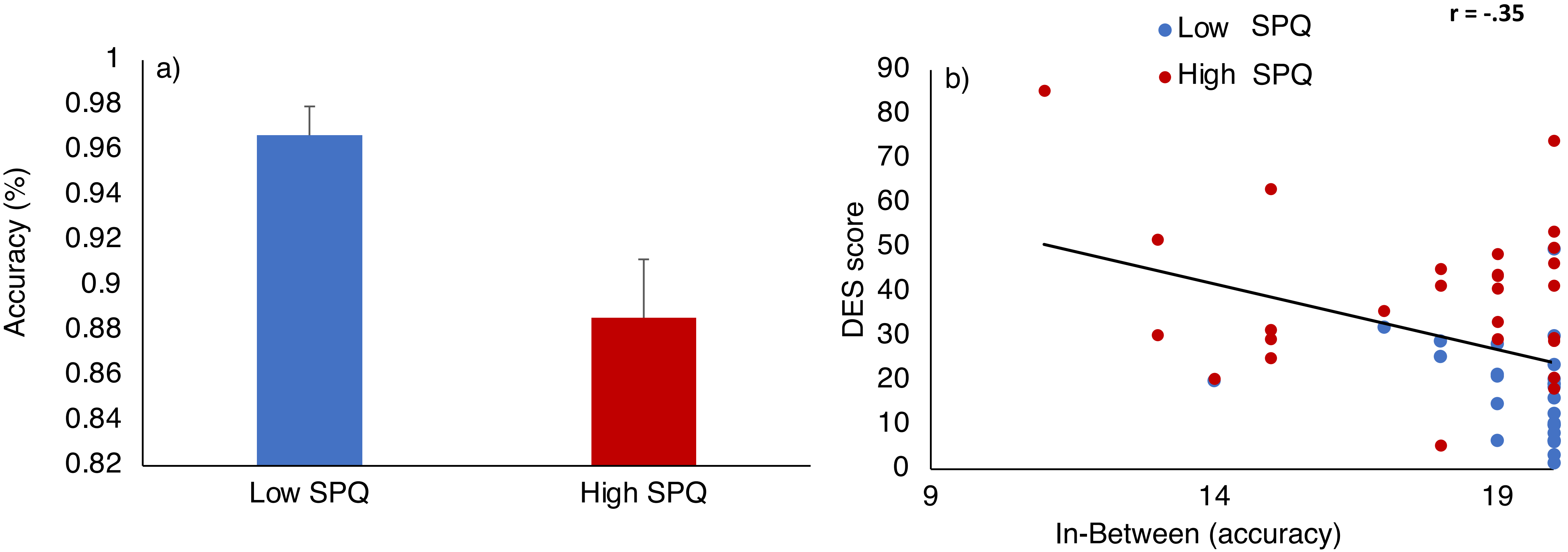

a)
Accuracy (%)
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.84
0.82
Low SPQ
High SPQ
b)
● Low SPQ
● High SPQ
r = -.35
DES score
90
80
70
60
50
40
30
20
10
0
9
14
19
In-Between (accuracy)

Figure 8

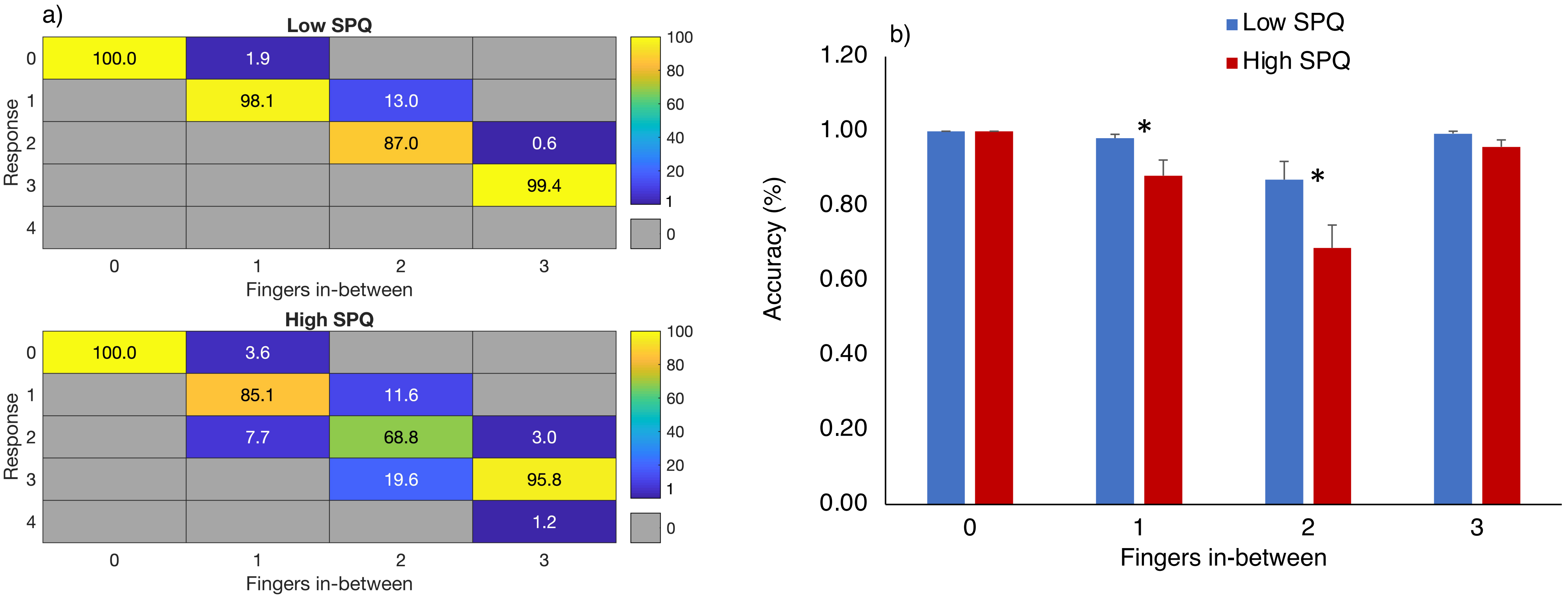
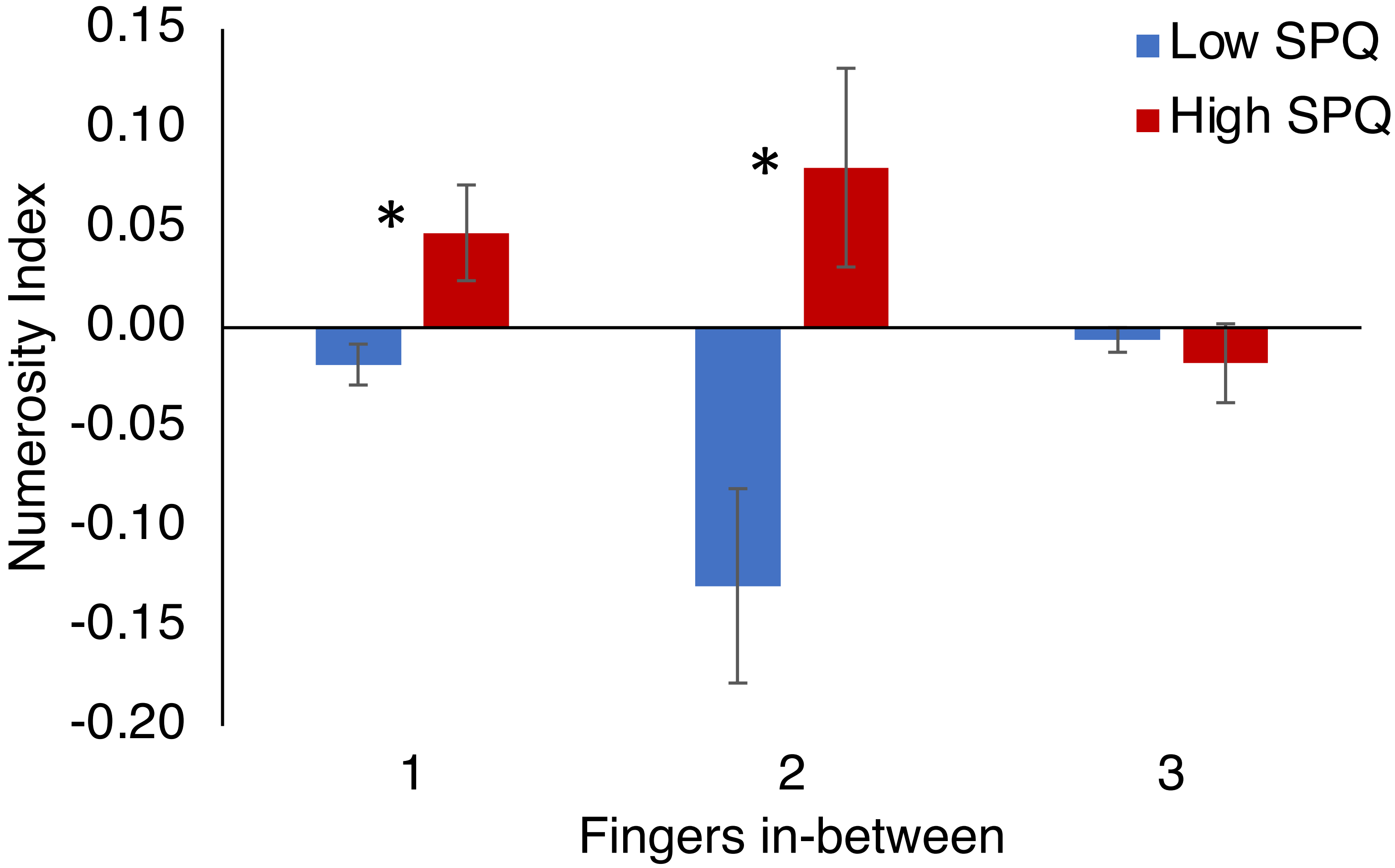

a)
Low SPQ
Response
0
1
2
3
4
100.0
1.9
98.1
13.0
87.0
0.6
99.4
0
1
2
3
Fingers in-between
100
80
60
40
20
1
0
High SPQ
Response
0
1
2
3
4
100.0
3.6
85.1
11.6
7.7
68.8
3.0
19.6
95.8
1.2
0
1
2
3
Fingers in-between
100
80
60
40
20
1
0
b)
Low SPQ
High SPQ
Accuracy (%)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
*
*
0
1
2
3
Fingers in-between

Figure 9



Numerosity Index
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Low SPQ
High SPQ
*
*
1
2
3
Fingers in-between