EEG correlates of impaired self-other integration during joint task performance in schizophrenia

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Abstract

Deficits in a wide variety of social cognitive processes are well established in schizophrenia. However, research focusing on actual interacting individuals is surprisingly scarce. Problems in low-level processes such as self-other integration may importantly underlie often-reported higher-level deficits. The current study aimed at measuring possible disturbances in self-other integration in schizophrenia using both behavioral and ERP measures. Sixteen healthy controls and fifteen schizophrenia patients performed a social Simon task in both a joint and an individual setting. Behaviorally, patients showed general slower reaction times, but comparable self-other integration as reflected in the social Simon effect. The ERP results for the healthy controls revealed increased no-go P3 amplitudes in the joint compared to the individual setting. Crucially, patients did not show this increase in no-go P3 amplitude. In line with previous research, the present ERP findings demonstrate that healthy volunteers needed more effort to inhibit their responses in the joint compared to the individual setting. Patients however, showed altered self-other integration when they had to withhold their responses while their co-actor had to act. These outcomes indicate that schizophrenia patients have deficits in low-level processes required for successful joint action.

Key words: schizophrenia; joint action; social Simon effect; self-other integration; P3 ERP
Introduction

Schizophrenia is a severe mental disorder that besides its positive (e.g., delusions, hallucinations) and negative symptoms (e.g., affective flattening, anhedonia) is also well known for its cognitive deficits (Kahn & Keefe, 2013). The importance of these neurocognitive deficits such as attentional problems (Luck & Gold, 2008), working memory deficits (Barch & Smith, 2008), and problems in executive functioning (Kerns et al. 2008) are extensively described and are pivotal for the deteriorated performance of these patients (Green et al. 2000). More recently, however, studies have revealed that social cognitive deficits also proved to be a key determinant of daily functioning of schizophrenia patients as reflected in the impact on functional outcome (Green et al. 2004; Brekke et al. 2005; Schmidt et al. 2011). Consistently, large mediating effects of social cognitive deficits in between neurocognitive symptoms and functional outcomes of these patients have been described (Fett et al. 2011).

Because of these insights, recent studies in schizophrenia have started to focus more on social cognition (Kahn & Keefe, 2013). However, most of these studies are of a rather passive nature, in which schizophrenia patients are, for example, asked to identify emotions that are presented either visually (Morris et al. 2009) or auditory (Leitman et al. 2010; Gold et al. 2012). Further, different Theory of Mind (ToM) paradigms have also been investigated giving more insights in disturbed mentalizing processes of these patients (Walter et al. 2009; Vistoli et al. 2011). However, very few studies so far have investigated possible social cognitive deficits in schizophrenia patients through the use of more active tasks, such as paradigms requiring joint task performance.
As in daily life situations where people interact with each other and perform tasks with one another, joint-task performance also requires the ability to anticipate and react appropriately to tasks and actions from the other person involved. This involves various cognitive processes such as ToM, social perception, and emotion processing (Green et al. 2008) but also the integration of the knowledge of the other person’s task. Studies have shown that when two people perform a task together, both persons also represent the task of the co-acting person (Sebanz et al. 2003). This is accomplished by the formation of so-called shared representations. The idea of these shared representations is in line with the common coding theory (Prinz, 1997; Hommel et al., 2001), which states that perceiving and action planning are functionally equivalent. Moreover, Sebanz et al. (2006a) proposed that the formation of these shared representations may be necessary for successful joint action.

A suitable task for investigating low-level processes central for joint task performance such as self-other integration is the ‘social Simon task’. This task is a variant of the classic Simon task where a task-irrelevant feature such as the spatial location of a stimulus (left or right of a central fixation cross), interferes with processing of the task relevant feature (color of the stimulus, which is mapped to a left or right button press). This interference, or the so-called Simon effect is reflected in slower reaction times (RTs) on trials where the spatial location of the stimulus is incompatible to the location of the response button (Simon & Rudell, 1967). Interestingly, recent studies suggest that when two people jointly perform the Simon task in a complementary way, both persons also represent the task of the co-acting person (Sebanz et al. 2003). In the social Simon task, the task is distributed over two participants, such that each participant is required to respond to only one color with a button press. The two participants are seated next to each other and the location of
the stimulus on the left or right of the computer screen may thus be compatible or incompatible to the sitting position of the participant. Although the location of the stimulus is also an irrelevant task-feature in the social version of the task, compatibility effects are still found. The amount of self-other integration is reflected in the so-called social Simon effect (SSE), i.e. slower RTs on incompatible trials where the stimulus is located on the side of the screen corresponding to the non-responding participant. Importantly, this SSE is no longer present when participants perform the same task on their own. Tsai et al. (2006) and Welsh et al. (2007) also pointed out that this SSE manifested itself only when a co-actor was really participating in a complementary way and not while a co-actor was passively observing the participant’s actions. The authors suggested that these results indicate that acting together or alone caused a difference in action planning (i.e., stimulus evaluation or response selection of the task), and being solely observed was not enough to activate the common coding system of self-other interaction.

Interestingly, previous studies found that self-other integration is not only reflected in the behavioral measurements of action planning, but that it is also observed in electrophysiological measures, i.e., the P3 event-related potential (ERP) component generated during action control (Sebanz et al. 2006b; Tsai et al. 2006). Furthermore, a joint-action ERP study of de Bruijn et al. (2008) showed that in a competitive setting inhibition P3 amplitudes differ among individuals depending upon the degree to which they integrate others’ representations. Taken together, these studies show that collecting ERP measures during joint-task performance is of great importance as they provide detailed measurements of brain activity associated with withholding a motor response (i.e., a no-go response) or controlling of an action (cf. Sebanz et al. 2006b). The studies of Sebanz et al. (2006b) and Tsai et al. (2006)
specifically demonstrated that no-go P3 amplitudes were increased when two persons perform the task together compared to when they perform the same task individually. Additionally, Tsai et al. (2006) showed that this increase in no-go amplitude was again only present in the joint condition and not in the ‘being observed’ condition. Accordingly, it was suggested that a no-go trial in a joint context, which is a go trial for the co-actor, activates the same action representation of the go response to be made by the co-acting individual. Therefore, stronger inhibition is required compared to a solo condition where no such integrated representation of a co-actor is formed on the same no-go trials.

As mentioned previously, it is well known that schizophrenia patients show disturbances in different aspects of social cognition like emotion recognition and ToM. However, it could be that more low-level processes of social cognition, such as self-other integration, may actually underlie these higher-level deficits in social behavior. So far, only one behavioral study investigated whether patients with schizophrenia also show disturbed self-other integration during joint action (Liepelt et al. 2012). Using a modified version of the social Simon paradigm they compared schizophrenia patients, first-degree healthy relatives of schizophrenia patients, and a group of healthy controls in the joint condition. They found that both healthy relatives and healthy controls show an SSE. Schizophrenia patients, however, did not show a significant SSE and seem to respond equally fast to compatible and incompatible trials. Based on the knowledge that schizophrenia patients have a disturbed sense of agency (Jeannerod, 2009; Schimansky et al. 2010), the authors assumed that the lack of an SSE in the group of schizophrenia patients primarily represents a social deficit.
Although these results suggest that schizophrenia patients have deficits in self-other integration, it is unknown whether social inhibition processes as reflected in the no-go P3 are also altered in schizophrenia patients during joint action performance. Also, as Liepelt et al. (2012) only employed the joint setting, it is unclear whether the reported disturbances are specific for joint performance or whether they are more general and also reflected at the individual performance level.

In the current study, we used the social Simon task to investigate differences in self-other integration between a group of schizophrenia patients and a group of matched healthy controls. To examine whether possible disturbances in joint performance are restricted to the social setting, both groups performed the task in two settings: (1) as a go/no-go task in an individual setting (seated next to an empty chair) responding to one color and (2) in a joint action setting where a co-actor who was seated next to the participant performed the same go/no-go task in a complementary manner responding to the other color. Additionally, since the degree of self-other integration is also reflected during action control or the performance of no-go trials, EEG signals were recorded during task performance in both settings. As a result, the aim of the current study was threefold: First, we want to investigate whether we can replicate the behavioral findings of Liepelt et al. (2012) demonstrating impaired self-other integration in schizophrenia patients through behavioral RT measurements of action planning, second by adding the individual setting we will gain more insight into the social specificity of possible modulations in joint-action performance, and third, by obtaining EEG measures we will be able to investigate whether possible disturbances in self-other integration in the group of patients are also reflected in the electrophysiological correlates of social action control.
Materials and Methods

Participants

Fifteen inpatients (recruited from the Psychiatric Hospital Onze-Lieve-Vrouw in Bruges, Belgium) and one outpatient together with sixteen healthy controls were recruited for participating in this study. For the group of patients, the diagnosis of schizophrenia was made by the first author according to the DSM-IV-TR (American Psychiatric Association, 2000) criteria using the Structured Clinical Interview for DSM Axis-I Disorders (SCID; First et al. 2002). Severity of the positive and the negative symptoms were rated by the same psychologist during a semi-structured interview using the Scale for the Assessment of Negative Symptoms and the Scale for the Assessment of Positive Symptoms (SANS and SAPS; Andreasen, 1983, 1984).

Patients were excluded for participation if their medication had changed 14 days prior to the assessment or if they had a history of substance abuse within 6 months prior to the assessment. Healthy volunteers were excluded in case of any psychiatric history and both groups had to be free of any other neurological condition.

The study was approved by the medical–ethical committee of the participating hospitals in accordance with the latest version of the Declaration of Helsinki and all participants provided written informed consent.

Design and procedure

Two chairs were placed in front of a 17” widescreen monitor positioned in the center. A 0.5 x 0.5 cm white fixation cross centered on a black background was permanently
visible during the task. Red or green circles with a diameter of 2 cm were presented 4.3 cm to either the left or the right side from the fixation cross.

Participants were seated either on the left side or the right side in a counterbalanced order and were asked to place their dominant index finger on the response button. Response buttons were the ‘w’ and ‘?’ key on a Belgian ‘azerty’ keyboard depending on whether the participant was seated on the left or right side respectively.

The experiment was divided into two conditions (see Figure 1): in the individual condition, participants were seated next to an empty chair performing a social Simon paradigm. During this social variant of a standard Simon task, participants actually perform a go/no-go task as it only requires a response (or withhold a response) with one hand depending on the color information. Depending on their seating location (left or right), they were instructed to press their assigned button only when a red or green stimulus was presented. In the joint condition, the participants performed the same go/no-go task and were all accompanied by the same male experimenter seated next to them performing the same task in a complementary way (i.e., responding to the other color). In order to increase comparability between both conditions, the no-go stimuli in the individual condition disappeared randomly between 300 and 400 ms after presentation, mimicking the responses of the experimenter during the joint condition. Both conditions were assessed with all participants in a counterbalanced manner.

In both the joint and the individual context, participants were provided with a noise-reducing headphone to ensure that the ERPs could not be influenced by the sound associated with the button presses.
Prior to each condition participants performed a short practice session of 16 trials and they were instructed to keep fixating on the fixation cross and respond as quickly and as accurately as possible to their target stimuli (red or green circle) irrespective of its location. In the joint condition, participants were additionally instructed that the co-actor seated next to them had to respond in the same way to the other color. To avoid a feeling of competition which is known to be of importance in influencing the SSE (de Bruijn et al. 2008; Hommel et al. 2009), the following extra instruction was given; “This task is not a competition. It is not about being faster. Try to perform the task as fast and correct as possible responding to the red (or green) colored circles while the other person will do the same responding to the green (or red) colored circles”.

Both conditions consisted of two blocks of 128 trials separated by a short break. In each block go and no-go stimuli were randomly presented: 64 trials with a spatially compatible stimulus-response relationship (i.e. a red circle to the left side of the fixation cross or a green circle to the right side of the fixation cross) and 64 trials with a spatially incompatible stimulus-response relationship (i.e. a red circle to the right side of the fixation cross and green circle to the left side of the fixation cross). Each trial began with a 1000 ms presentation of the fixation cross followed by the stimulus. The stimulus disappeared immediately after response or rested for a maximum of 1500 ms in case no response was given. The total duration of the experiment was approximately 30 minutes.

<Insert Figure 1 here>

Electrophysiological recordings
Thirty-one active electrodes (ActiCap, Brainproducts, Munich, Germany) were used for electrophysiological recordings. EEG was recorded with 27 scalp electrodes arranged according to the 10-20 system. Electro-oculography recordings were also collected for vertical and horizontal eye movements by placing electrodes above and below the right eye and at the outer canthi. Recordings were online referenced to the left mastoid at a sampling rate of 500 Hz.

Using BrainVision Analyzer (2.0) software, electrodes were offline re-referenced to both mastoids and digitally filtered with a 0.5-8 Hz band-pass filter (Sebanz et al. 2005). Ocular artifacts were removed using Independent Component Analysis (ICA). Data was further segmented in epochs starting 200 ms before stimulus onset and ending 1000 ms post-stimulus and baseline corrected and averaged relative to a 200 ms pre-stimulus baseline. The P3 ERP component was defined as the most positive peak (automatic peak detection; one data point) in a 200-800 ms post stimulus time window in individual average waveforms.

**Analyses**

SPSS (version 20.0; SPSS Inc., Chicago, Ill) was used for statistical analyses. All trials with RTs below 150 ms and above 1000 ms were excluded from averaging and further analyses (de Bruijn et al. 2008, 2011; Liepelt et al. 2012, Houthoofd et al. 2013). Average RTs and error rates were entered in 2x2x2 repeated measures general linear models (GLM) with within subject factors condition (individual, joint) and compatibility (compatible, incompatible), and between subjects factor group (patients, healthy controls).

For the amplitude and latency analyses of the parietal P3(b) ERP component during action planning electrode site Pz was used (Roth et al. 2007; Brazil et al. ...
2012) in a 2x2x2 repeated measures GLM using within subject factors Condition (individual, joint) and Compatibility (compatible, incompatible), and between subjects factor Group (patients, healthy controls). For analyzing the amplitudes and latencies of the more frontocentrally pronounced P3(a) ERP component during action control, the additional within subject factor Electrode (Fz, Cz) was entered in a 2x2x2x2 repeated measures GLM.

All significant interactions were further investigated with follow-up analyses.

**Results**

*Clinical and sociodemographic data*

One patient had to be excluded from all analyses because of non-compliance. Analyses were conducted with fifteen patients and sixteen healthy controls and no significant group differences were found (See Table 1).

<Insert Table 1 here>

*Behavioral data*

Errors were infrequent for both healthy controls (1.0%) and schizophrenia patients (1.3%) and were removed from the datasets and further analyses.

Figure 2 depicts the mean RTs for the different conditions and the two groups. RT analyses revealed no significant main effect of Condition \(F_{(1,29)}=2.47, p=0.127\]. The main effect of Group was significant \(F_{(1,29)}=12.28, p=0.002\) indicating that patients had generally slower RTs (\(M=457\) ms, \(SD=77.9\)) than healthy controls (\(M=383\) ms, \(SD=38.4\)). The main effect of Compatibility was significant \(F_{(1,29)}=12.30, p=0.002\).
Importantly, however, the interaction between Compatibility and Condition was also significant \( F_{(1,29)}=13.78, p=0.001 \). Follow-up analyses of this interaction across groups revealed only a significant effect of Compatibility in the joint \([M=11.8 ms, SD=15.7; F_{(1,29)}=19.12, p<0.001]\), but not in the individual setting \([M=0.1 ms, SD=10.1; F<1]\), indicating the presence of a social Simon effect (SSE) for both groups in the joint condition only. The three-way interaction, however, was marginally significant \( F_{(1,29)}=3.31, p=0.079 \). Subsequent exploratory analyses suggest that this might be due to a marginally significant larger compatibility effect in the joint condition for the group of patients \((M=17 ms, SD=16.6)\) compared to healthy controls \((M=7 ms, SD=13.4; t_{(29)}=1.94, p=0.063)\).

**ERP analyses: Action control (No-go P3)**

Figure 3 depicts the no-go P3 grand average waveforms at electrode Fz and Cz for the different conditions and both groups. Neither the main effect of Condition \( F_{(1,29)}=1.72, p=0.200 \) nor the main effect of Compatibility \( F<1 \) reached significance. The main effect of Electrode was significant \( F_{(1,29)}=22.23, p<0.001 \) showing smaller amplitudes at electrode Fz \((M=7.34 \mu V, SD=5.22)\) compared to Cz \((M=9.34 \mu V, SD=5.54)\). The main effect of Group was also significant \( F_{(1,29)}=5.04, p=0.033 \), showing generally lower no-go P3 amplitudes in the group of schizophrenia patients \((M=6.54 \mu V, SD=4.19)\) compared to the healthy controls \((M=10.14 \mu V, SD=5.94)\). Importantly, however, the interaction between the factors Condition and Group was also significant \( F_{(1,29)}=5.90, p=0.022 \). Follow-up analyses revealed that healthy controls displayed increased No-go P3 amplitudes in the joint condition \((M=11.32 \mu V, SD=5.94)\) compared to the individual setting \((M=1.01 \mu V, SD=3.45)\).
SD=6.46) compared to the individual condition (M=8.96 µV, SD=5.14; F(1,15)=5.10, p=0.039; See figure 4). Patients however, did not show a significant difference in amplitude between the joint (M=6.19 µV, SD=3.42) and the solo condition (M=6.89 µV, SD=4.85; F(1,29)=1.09, p=0.314). Also, analyses for the two conditions separately showed that no-go P3 amplitudes were specifically reduced for schizophrenia patients in the joint condition (patients: M=6.19 µV, SD=2.9; controls: M=11.32µV, SD=6.7; F(1,29)=8.68, p=0.006), but not in the individual condition (patients: M=6.89 µV, SD=4.9; controls: M=8.96 µV, SD=4.1; F(1,29)=1.47, p=0.235). All other interactions were not significant [All Fs<2.48, all ps>0.126]. The P3 peak analyses on action planning (go-trials) revealed no significant main effects or interactions (main effects: all Fs<3.19, all ps>0.085; interactions: all Fs<1.72, all ps>0.200).

Discussion

Using the social Simon task, we compared a group of schizophrenia patients with a group of matched healthy controls and investigated whether patients' levels of self-other integration during joint-task performance differed from that of controls as reflected in both behavioral and electrophysiological measurements.

The behavioral analyses demonstrated that (1) patients had generally slower RTs than healthy controls but that (2) overall, both groups showed comparable compatibility effects in the joint condition. Moreover, the ERP results showed that (3) healthy controls had increased no-go P3 amplitudes in the joint condition relative to
the individual setting. Patients importantly however, did not show this difference in no-go P3 amplitude between the two conditions. We will further discuss these findings in light of previous research.

The overall slowing in responses of the schizophrenia patients is not an uncommon finding. General psychomotor slowing or retardation has been repeatedly demonstrated in this clinical population (for a review see Morrens et al. 2007; Docx et al. 2012) and is probably related to abnormal dopaminergic functions in the striatal regions. Please note that possible influences of medication on these processes cannot be completely ruled out. In the group of patients however, analyses of the impact of antipsychotic medication, did not reveal a significant correlation between chlorpromazine equivalents and RTs.

Interestingly, despite this general slowing, the current study demonstrates that like healthy controls, patients with schizophrenia show a comparable SSE during joint-action performance, possibly reflecting a similar degree of self-other integration. Our findings even suggest that the SSE in the group of schizophrenia patients may be larger than the SSE in the group of healthy controls, suggesting a tendency for increased self-other integration at a behavioral level in the patients. However, we are cautious in interpreting this finding at this point, as the relevant interaction was only marginally significant. More research with larger populations is necessary to investigate this further. The currently found results in healthy controls are in line with previous studies using similar paradigms (Sebanz et al. 2003; Sebanz et al. 2006b; Tsai & Brass, 2007). The finding of intact self-other integration in the schizophrenia patients, however, is at odds with a recent study by Liepelt et al. (2012) who demonstrated that in contrast to healthy controls and first-degree relatives of patients with schizophrenia patients with schizophrenia did not have an SSE in the joint
condition. The authors argued that this may be caused by a primarily social deficit in the sense that patients with schizophrenia have a specialized deficit in the integration of actions produced by self and other.

Interestingly, our ERP findings did reveal group differences in neural activations when processing no-go stimuli. Results revealed an increase in no-go P3 amplitude during joint task performance but only for the group of healthy controls. This increase in no-go amplitude for the controls is in line with previous work by Sebanz et al. (2006b) and Tsai et al. (2006). These authors concluded that in a joint setting where people also implement the actions of others into their own action program, more effort is needed to inhibit a response on a no-go trial as that trial requires an active response of their co-actor. In other words, healthy controls need more action control when performing a task in a complementary manner. Patients however, did not show this increased effect of action control during joint performance, suggesting that they do not need to generate more inhibition when working together with another person. We believe that this lack of an increase in amplitude in the group of patients is the result of a deficit in self-other integration. It seems that when patients do not have to act themselves, they do not integrate the required go action of their co-actor and therefore patients do not need to exert more action control as reflected in increased inhibition.

One could argue, however, that this aberrant ERP pattern of action control is the result of a more general impaired inhibition system in the group of schizophrenia patients since it is well known that these patients do show deficits in response control (Mathalon et al. 2000; Weisbrod et al. 2000; Fallgatter & Müller, 2001; Ford et al. 2004; Ford et al. 2010). Our data also showed an overall reduction in no-go amplitude in the group of patients. Therefore additional analyses for the two
conditions were performed and importantly showed that no-go P3 amplitudes were similar for the two groups in the individual but not in the joint setting. Consequently, the differences in no-go P3 amplitude seem to be driven by the social context and thus indicate that patients with schizophrenia show reduced integration of a co-actor’s actions into their own action program. However, we would like to note that it is impossible to completely rule out possible effects of antipsychotic medication on ERP amplitudes (Ford et al. 1994).

Although the current study could not replicate the behavioral pattern reported by Liepelt et al. (2012), both studies provide support for impaired self-other integration in patients with schizophrenia. Liepelt et al. (2012) showed this at the level of action planning through behavioral measurements while the current study showed this at the level of action control through electrophysiological measurements. A possible explanation for the divergent outcomes may be related to differences in methodology, e.g., the type of stimuli used which may have led to different stimulus encoding strategies (Miles & Proctor, 2012). Perhaps the use of colored circles in this study demanded a different cognitive encoding strategy compared to the use of arrows pointing to the left or right in the study of Liepelt et al. (2012). Yet, another difference between the current study and the one reported by Liepelt and colleagues is that in the latter participants did not perform the same paradigm in an individual setting, therefore it is unknown for example, whether similar deficits were also present when performing the task alone. Also, the use of a confederate to partake in the study of Liepelt et al. (2012) compared to the jointly performing experimenter in the current study might influence the SSE and should be further investigated. Finally, it remains unclear whether possible differences between the severities of symptoms could account for different outcomes between the two studies. However a direct
comparison is not possible since different scales are used to measure the severity of positive and negative symptoms.

Although the current behavioral results are in contrast with the results of Liepelt et al. (2012), the so-called referential coding account (Dolk et al., 2013, 2014) could explain the current findings. This integrative account states that action selection consists of activating the codes representing the features of all perceivable effects (e.g., the seen location). So if a stimulus on the left side is presented, the code for left will be activated enhancing a response to be made on the left side and interfering with a response to be made on the right side. However when jointly performing a task, the self-related codes can overlap with the other-related codes depending on the perceived similarity between oneself and the other (Dolk et al., 2014). Assuming that schizophrenia patients are known to be impaired in discriminating between self-performed actions and others’ actions (Heinks-Maldonado et al., 2007; Ebisch et al., 2013; Backasch et al., 2014) one could argue that these patients actually have an increased perceived similarity between themselves and the co-actor, enhancing the salience of the spatial location resulting in an SSE. From this line of reasoning, especially the numerically larger SSE of the patients is not unexpected. Moreover, the finding is also in line with studies demonstrating intact SSEs in patients with social deficits such as individuals with autism (Sebanz et al., 2005) and patients with lesions resulting in ToM problems (Humphreys & Bedford, 2011).

With regard to the present differences in ERP and behavioral outcomes, we propose two possible explanations both related to known cognitive processing limitations in schizophrenia patients. First, it seems that patients with schizophrenia show specific problems in self-other integration when they do not have to act themselves (i.e., ERP results), but that self-other integration may be relatively spared
when an action is required (i.e., behavioral results). This suggests that self-other integration triggered by processing the irrelevant stimulus information (i.e., the location), may take place after color information has been fully processed. Due to impaired cognitive processing, patients may use a different strategy in which they first process the relevant stimulus information and only continue processing the irrelevant information when the color requires them to act. In the case of a no-go stimulus, patients may thus not continue processing the irrelevant information, as processing has stopped after identifying the color, which indicated that no action is required. Healthy volunteers are more likely to use a faster strategy in which these two processes take place simultaneously or largely overlap (Baroni et al. 2012; see also Hommel’s (1993) temporal overlap hypothesis). Alternatively, the divergence between behavioral and ERP findings in the current study may result from differences in processing task instructions. During the joint condition, participants receive the additional instruction about the co-actor responding to the other color. Because of cognitive processing deficits, it is plausible to assume that patients process this instruction more self-centered in order to avoid a possible higher cognitive load. This way, patients especially focus on their own task, perhaps even ignoring the task of the other so there is no need for more response inhibition in the joint compared to the individual setting (cf. de Bruijn et al., 2008).

Please note that these explanations remain speculative at this point and more research is needed to investigate these issues in more detail. For example, dedicated studies in healthy and psychiatric populations comparing different stimuli modalities and specific instructions biasing one’s attention are necessary to gain more insight, or studies investigating the impact of cognitive processing limitations on joint task performance.
To conclude, the present study is the first to provide support for decreased self-other integration in schizophrenia patients at an electrophysiological level. The currently found opposing behavioral and electrophysiological findings seem to suggest a specificity of impaired self-other integration during action control, but not during action planning. More recent interpretations of the behavioral SSE (see e.g., Dolk et al., 2013, 2014) argue that the effect is not necessarily social in nature. From this perspective, the current study additionally shows that the electrophysiological correlate of shared task representations as reflected in the no-go P3 component may be a more sensitive and reliable measure of self-other integration than the behavioral SSE alone. Although future research is warranted to investigate the role of referential coding processes in schizophrenia in more detail, the current outcomes strongly suggest that in line with Liepelt et al. (2012) patients with schizophrenia do not co-represent their co-actors’ actions to the similar extent as healthy controls. These low-level impairments in self-other integration may importantly underlie problems in more high-level social cognitive processes such as ToM or social decision making (Liepelt et al., 2012). When low-level attentional problems exist, important social cues are easily missed or misinterpreted resulting in inappropriate social responses in a variety of behaviors. These particular problems are clearly evident in daily life functioning of patients with schizophrenia and importantly result in poor functional outcomes. Hence, the current outcomes stress the importance of future research dedicated at investigating the interplay of these different processes in this disorder.

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References


Figure 1. Task setup of the Social Simon task. The participant sitting on the right responds to the same color of the stimulus in both the individual (left) and the joint setting (right).

85x29mm (300 x 300 DPI)
Table 1. Clinical and sociodemographic data.

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SAPS = Scale for the Assessment of Positive Symptoms; SANS = Scale for the Assessment of Negative Symptoms

Values shown are absolute or means with SDs between parentheses.
Figure 2. Mean reaction time as a function of spatial stimulus-response compatibility per condition (individual, joint) and per group (patients, healthy controls). Error bars represent standard errors of the mean.

78x35mm (300 x 300 DPI)
Figure 3. Grand average stimulus-locked waveforms showing no-go P3 ERP amplitudes for the different compatibility conditions and different settings at electrode sites Fz and Cz for both healthy controls (left) and schizophrenia patients (right).
Figure 4. Difference waveforms (joint minus solo condition) of the stimulus locked no-go P3 grand average for healthy controls (A) and schizophrenia patients (B) at electrode site Fz. Topographical distribution of the difference waves showing the frontocentral distribution for the maximal no-go P3 peak amplitude in healthy controls (C). Darker red colors indicate more positive amplitudes.