

*Full Length Research Paper*

## Social memory performance in schizophrenia

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The advance of social neurosciences is by and large dependent on the circumscription and measure of specific social-cognitive competencies. The importance of accurate neuropsychological tests emerges in this context as a decisive step to the evolution of the field as a whole. This paper has three interconnected goals: to shed light into a previously unreported social cognitive dimension and to introduce a software-based, multilingual neuropsychological test to assess and quantify performance under it; to validate the test for neurocognitive assessment in schizophrenia and to establish brain correlates of differences in performance in a cohort of patients with schizophrenia. The competence under consideration is called social memory and this relates to the ability to recall social information. Its conceptual validity stems from differences in performance when recalling human (H) vs. non-human figures (NH). The new test is called social memory test (SMT). Here we present the validation of SMT and its application to assess brain correlates of performance in a cohort of medicated adult patients with schizophrenia using diffusion tensor imaging (DTI). Cronbach's  $\alpha$  was above 0.7 on the clinical sample, and above 0.58 on the control group. Results suggest that the test is a reliable instrument to assess social memory in schizophrenia, and that performance is correlated to visual memory and social cognition. Neuroimaging results warrant an important role to Heschl's gyrus, thus suggesting that semantic processing is chiefly tied to this social-cognitive competence.

**Key words:** Social memory, neuropsychological assessment, social cognition, schizophrenia, DTI.

### INTRODUCTION

#### Social intelligence and deficits in Schizophrenia

The history of the cognitive sciences is characterized by a shift from the presumption that 'cold' computation

resources drove the evolution of the human mind and still define its basic functioning as an information processing

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system to the idea that socially and subjectively embodied resources have a prominent role in this regard (Thagard, 1989). Considering performance as an approach to face this dichotomy, the maximization of 'cold' information processing skills is based on a set of formal rules to transpose and transform chunks of mental content (what we call 'logic'). However, social and emotion cognition have their performance maximized as they impact others in a way that the development of intentional plans of action move forward. Correctness and wrongness are contingent to the specific context in a much stronger sense. Those resources are the base for social functioning, and its impairment is present in a wide range of psychiatric disorders, including psychosis as schizophrenia (Penn et al., 1997; Pinkham et al., 2003).

In the 1980s and early 1990s, researchers argued that the non-social or 'cold' cognition is not enough to elucidate all the disabilities observed in schizophrenia, opening the debate about the social cognitive deficits in this disorder (Penn et al., 1997). Social intelligence can be defined as the process of applying "social content, information and knowledge" to achieve functional outcomes in interpersonal settings (Bar-On et al., 2003). After decades of discussion, the picture that emerges is one where only two social intelligent processes became widely accepted as present in all human cultures: theory of mind (TOM) and empathy. In principle, both can be used to categorize performance and, in that sense, could be part of a social intelligence index. Nevertheless, as we have argued elsewhere, there are pitfalls to be dealt with (Ando et al., 2013).

Empathy has both cognitive and affective components (Kerem et al., 2001); the latter involves embodied manifestation of approval, whose spontaneous nature hampers evaluations of the kind. One tends to act in a more or less empathic manner according to spontaneous bonds, whereas cognitive performance must be measured as a function of the capacity to satisfy intentional plans; this is behind the fact that available empathy tasks are exclusively focused on testing whether a person shows empathic reactions or not that is, (Chlopan et al., 1985; Spreng et al., 2009), leaving behind the possibility to test normal people on the degree of expertise in relation to this trait.

TOM is a much more reliable component of social intelligence, since it is less dependent on the affective engagement produced by the stimulus. Moreover, the ability to portrait the intentions behind a behavior is, in part, a matter of figuring feasible reasons for its existence, which is obviously closer to cartesian rationality than is empathy. Specifically to schizophrenia, the National Institute of Mental Health (NIMH) has define 5 relevant domains of social impairment, including TOM, social perception, social knowledge, attributional bias and emotional processing (Green et al., 2008). As in other disorders, TOM has been extensively studied in schizophrenia, as well as emotion perception. Regardless

of this fact, all of the 5 domains seem to be affected in schizophrenia and patients with this disorder perform poorly than normal control in tasks testing abilities (Savla et al., 2012).

The effort of associating cognitive and neural findings of social functioning was the move made by authors that pioneered conceptual frameworks in modern social cognitive studies (Baron et al., 1985; Gordon, 1986; Premack, 1988; Premack and Woodruff, 1978). Their work supported the foundation of a whole new tradition in the field, which flourished in neuroscience, leading to a deflation of importance to lateral prefrontal brain structures in the understanding of the biocomputational structures that support human-specific trends, in favor of a more holistic view, including several other brain regions and complex networks, that is, orbital/middle-frontal, parietal, fronto temporal connectivity, and so on.

Researchers have shown abnormalities in some of these brain areas in schizophrenia, which can play a whole in the social deficits in this psychosis. Smaller brain volume, including the frontal cortex and amygdala, and smaller size of the neurons in the prefrontal cortex are consistent findings (Pinkham et al., 2003). The whole of the lateral fusiform area in schizophrenia deficits, also called fusiform face area, is also a focus of intense investigations, with some contradictory results. Yoon et al. (2006) argued that this area, as well as their performance, shows similar activity compared to health controls in a perceptual face one-back task. In the other hand, Walther et al. (2009) found both encoding and face recognition abnormalities and those associated to a low activation of the right fusiform face area. A more recent work has shown impairment in memory for faces, despite the expression in patients with schizophrenia in a repetition priming task, and the decreasing in performance was associated to an abnormal activation of the left fusiform gyrus (Schwartz et al., 2012).

Facing this conceptual panorama, it is compelling to quest for the core and most basic dimensions of social and emotional information processing, that is, for mental processes whose simple structure permeates all human cultures and strongly correlated to well-defined stages of human neurodevelopment. This new perspective not only gave birth to the fields of social cognition and social neuroscience as it showed that it would be feasible to circumscribe a set of elementary social intelligent processes and, tied to them, a set of validated neuropsychological tests applicable with some variations to normal individuals of all ages and psychiatric patients, that would be accepted in the field as a social intelligence index (Baron et al., 1999; Cantor and Kihlstrom, 1987; Kaukiainen et al., 1999; Marlowe, 1986). However, this does not warrant multiple ways of testing it as to our knowledge, there is only one open-source software-based test that can be used to rank performance of normal individuals: the Inverted Comic Strips Task (Ando et al., 2013), whereas only behavioral evaluations stand among TOM as a

measurable component of social intelligence (for a review of other types of social intelligence tests, (Bar-On, 2000; Conte, 2005). This picture suggests the necessity to conceive and manage through cognitive evaluation other candidate components, in order to fully develop the concept of social intelligence.

### **Expanding possible measurable dimensions of social intelligence**

Why is that the capacity to prospect intentions remain as the only dimension assessable in non-naturalistic contexts? Our hypothesis is that this has much to do with the challenges involved in generating social cognitive tests that simultaneously map into very specific cognitive processes and carry the necessary ecological validity to be accepted in this field. We believe that three *sine qua non* features of social interaction must take part in these: predominantly non-verbal structure, sensitivity to human figures as they appear in interpersonal relations (expressive faces, bodies and actions), and intentional/purposeful structure. This last factor is probably the most challenging.

Social relations are imbedded in a context of purposeful actions and counter-actions (Malle and Moses, 2001; Marlowe, 1986; Searle, 1983). In such, social intelligence is substantiated as a set of affective-cognitive and behavioral processes that functionally respond to interpersonal demands and that are activated as a type of heuristics by simple exposure to the appropriate context (for inspirational ideas to the formulation of this proposition, (Salovey and Mayer, 1989; Sternberg and Detterman, 1986). Assuming such constraints, we hypothesize that a particular facilitation to encode and retrieve episodic information intrinsically associated to social stimuli may add to this set of basic competences. That is, there may exist a particular type of memory facilitation for humans as they appear in interpersonal contexts (expressive, purposeful) that helps us deal with a great number of people who we once interacted with (therefore, intentional content), in most case through heuristic inference (Evans, 1984).

A commonly held assumption is that our ability to recognize faces and classify people who we have interacted with in the past is superior to our capacity to do the same with non-human stimuli. Anecdotal data suggest that we remember people with which we dealt with in a way that we don't remember microwave ovens or pets from different pet shops. To the extent that it holds, this represents a type of 'cocktail effect' that allows us to recognize and deal with someone with which we interacted with in the past, but haven't seen for a long time, despite our incapacity to remember her name and other contextual details that go beyond the general sense brought by the person's traits and their expressive patterns.

This assumption is in line with Weigel et al. (2013) recent findings of a developmental specificity favoring face memory, which should be understood as a separated construct than face perception (Weigelt et al., 2013).

We hypothesize that such capacity may represent an integrative by product of our special sensitivity to human-like traits with our special sensitivity to active/intentional encodings. Mental processes involved in stimuli recollection after passive exposition (the one present in traditional memory tests) are different from the processes involved in recollection after active/intentional manipulation of information, much as it applies to the way by which we deal with other persons - in opposition to the way that we deal with inanimate objects (the way we deal with animals is somewhere in between). Social cognition is all about intentionality in the real world (Searle, 1983) and recollection of social information precisely reflects our role in heuristically encoding and retrieving what we implicitly assume as significant.

In more specific terms, there may be a tendency to encode and retrieve information regarding someone's 'digital impression' in the real world (where we act as intentional agents in the process of implicitly or explicitly determining which are the relevant features) that is distinct from other types of memory, not only in terms of its descriptive/superficial aspect - the use of species-specific components as 'landmarks' for implicit classification and recognition, that is, for heuristic inference - but by its superior cognitive potential in relation to similar employments of non-human information. To the extent that such enhanced capacity to make use of human-related inputs exists, we hypothesize that it may be at the heart of the ability to strengthen weak social ties over time.

A lot of progress has been made either in the neurobiological basis as well as in the cognitive aspects of the social intelligence. However, specially related to the impact of social cognition in schizophrenia deficits, inconsistency in the findings and gaps in measurement remain to be elucidated. The Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS) Consensus Cognitive Battery reflects the effort in creating standardized methods for research in the field but, still, there is only one task that measures social cognition in this battery: the Mayer-Salvey-Caruso Emotional Intelligence Test (Nuechterlein et al., 2008). The NIMH address the need of differentiating social cognitive from nonsocial cognitive domains, and they claim that "psychometric properties of current social cognitive measures for schizophrenia are generally inadequate on unknown" (Green et al., 2008).

Apart from sociological studies (Olick and Robbins, 1998), the concept of social memory appeared in the literature in the 1980's under two different lines of research: social-investigatory behavior of animal models under different conditions (Dantzer et al., 1988; Thor and Holloway, 1982) and social context effects on memory

(Wyer and Srull, 1986). This is the first time that it appears imbibed in concerns about human intelligence in the real/social world, as well as in the schizophrenia scenario.

## Objective

In this paper we introduce: a conceptual framework to deal with the idea of social memory as a potential component of social intelligence; links and data for the validation of a new software-based social memory test (presented in two versions, one for kids and one for control), which can be applied to both normal individuals (14 years-old and older) and psychiatric cohorts; data on brain correlates of social memory in schizophrenia, using diffusion tensor imaging (DTI). The aim of this last procedure is to better understand how differences in performance in this test relate to alterations on the brain morphology and, more specifically, to neural circuits that are known to be affected by the syndrome. Considering that schizophrenia is believed to involve strong social components that affect intellectual performance, one may assume that in this last part of the study, light is being shed into the feasibility of using the new social memory test (SMT) to screen patients' cognitive performance, beyond what instruments focused on 'cold' mental traits can provide.

## METHODOLOGY

### Participants

As an inclusion criterion, healthy individuals with age between 18 and 35 years were included on the control group. Individuals in the control group had to score less than 7 points on Psychiatric Screening Questionnaire (SRQ-20) (Berwick et al., 1991), a brief psychiatric screening questionnaire, and have neither psychiatric nor neurological disease historical. Participants with schizophrenia were outpatients from PROESQ-UNIFESP, a day treatment program dedicated to schizophrenia and related disorders. All of them were diagnosed by the DSM-IV criteria and with age between 18 and 50 years old were included in the clinical group. All participants read and signed the informed consent document for this research and the study was approved by the ethical committee of the institutions where the study was developed. The socioeconomic data was also collected. The sample details are presented in Table 1.

### Neuropsychological validation

#### Structure of the SMT

The two software-based versions of the social memory test (SMT) were created using a mix of computational languages. The run in the browser, are responsive and offered in English and Portuguese, free of charge. Basic statistics are provided through automated analyses using R. Links which can be found in the appendix. Content of the test is centered on the idea of letting subjects designate features to humanized and zombie-like avatars and test whether differences in retrieval occur. All figures were constructed

using Life Studio Head Editor software. Human-like features are: hair color, eye color, skin tone, expressive facial musculature. To code the latter, we relied on Eckman's Facial Acting Coding System (FACS) (Polikovsky et al., 2010). Since the test itself is one of our results, we will describe it in the next section. The features intentionally defined by the subjects are typical 'social tags': name and profession.

The test is meant to be graphically inspiring, an important aspect regarding the participant's adherence to the task (Mayer and Estrella, 2014) which is, according to our perception, neglected on the design process of most scientific test interfaces. It runs as follows: the participant is presented to a group of 12 faces in the screen and a panel with 12 names, which he can freely use to tag the avatars. Next, they move to a screen where they are confronted with four empty boxes, each of which related to a specific profession (as shown below); the task in this phase is simply to designate a job to each figure. After that, figures disappear and, one at a time, in a pseudo-randomized order, they appear in the center of screen, along with the profession boxes, which are now empty again (Figure 1). The goal is to drag and drop the figure in the appropriate profession box. Same thing is done for the zombie-like figures, in a pseudo-randomized order, so that half of the subjects proceed from normals to zombies and half the other way around. In this sense, the social memory test formally involves recollection of a 12/4 distribution. This number was established after a pilot study results normalization (Figure 2).

The idea of social memory as a component of social intelligence relies on the possible existence of differences in professions recollection for the two (pseudo-randomized) versions of the same test: one carrying avatars portraying human like features and another portraying zombies. Nevertheless - and here is tricky part - one should bear in mind that differences in performance should not be used as a sign of social intelligence, but only of pro-social memory skills. It proves that we are in the right track, but did not provide us with parameters for social intelligence evaluation, which is better represented by the score in the version that contains human-like avatars.

Relative performance only determines whether the person is differentially sensitive to social vs. non-social stimuli. Once this has been established as an experimentally valid idea, performance in absolute terms should be considered simply as the ability to intentionally select, encode and retrieve information that can be used to deal/identify another person.

#### **Criteria for selecting tests that were used in the validation battery**

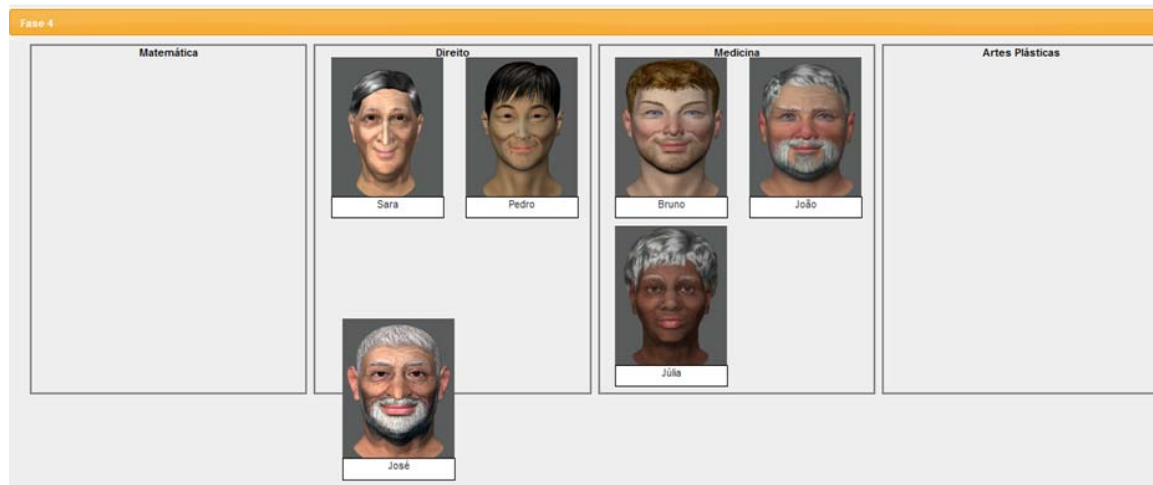
The perspective drawn above raises the question of whether social memory is more related to other social capacities or to cold cognitive capacities (example, working memory). This drove the selection of the tests that were included in our validation battery. In this vein, we applied neuropsychological battery, which included: Wechsler Abbreviated Scale of Intelligence (WASI) subscales: Vocabulary and Matrix Reasoning (Wechsler, 1999) for estimated IQ assessment; Rey-Osterrieth Complex Figure Test (ROCF) (Shin et al., 2006), a visuo-spatial memory test and Faux Pas recognition test - adult version (Stone et al., 1998) a high level theory of mind test. The choice for the Faux Pas recognition test follows others (de Achával et al., 2010; Hasson et al., 2014; Martino et al., 2007) that found TOM deficits in patients with schizophrenia using this instrument.

#### **Brain correlates of performance in a cohort of patients suffering with Schizophrenia**

Considering the role that social cognition exerts in schizophrenia



**Figure 1.** Comparison of human and zombie avatars.



**Figure 2.** SMT group selection screen.

**Table 1.** Demographic and clinical characteristics of participants.

Parameter	Schizophrenia (n = 50)		Control (n=150)	
	Mean	SD	Mean	SD
Age (years)	38.62	10.41	23.05	4.97
SRQ-20	6.45	4.86	2.15	1.84
Socio-economic status <sup>a</sup>	23.53	6.71	32.75	7.59
Gender (male/female)	28/22	-	72/78	-
Age at disease onset	22.62	5.71	-	-
Duration of illness	13.68	7.627	-	-
PANSS <sup>b</sup> total	50.88	11.359	-	-
PANSS <sup>b</sup> positive	11.53	3.808	-	-
PANSS <sup>b</sup> negative	14.71	5.066	-	-
PANSS <sup>b</sup> general	25.24	5.774	-	-
Drug (mg/day, OLZP equivalent) <sup>c</sup>	17.29	6.46	-	-
Clozapine use (yes/no)	13/37	-	-	-
Clozapine dose(mg/day)	478.13	120.59	-	-

<sup>a</sup>According to Brazilian Criteria of Economic Classification (CCEB). <sup>b</sup>Positive and Negative Syndrome Scale. <sup>c</sup>Olanzapine equivalents were calculated according to international consensus of antipsychotic dosing (Gardner et al., 2010).

and the overall interest in brain correlates of social impairments (and the opposite) in the syndrome, we decided to investigate whether differences in performance on SMT in a population of chronic patients attending to a public day clinic were correlated with the reduction of fractional anisotropy (FA). 26 chronic patients (18 to 50 years) from PROESQ-UNIFESP clinic underwent the procedure.

DTI was obtained using EPI, from a Siemens Sonata Maestro Class 1.5 Tesla device. 150 DTI images were acquired using the following axial sequence: RT= 7500 ms, ET= 102 ms, matrix 128 X 128, vision field = 26 cm, thickness = 3.0 mm, no spaces between slices. Images with 2 different b values were obtained (0 and 1000 s/mm<sup>2</sup>). A total of 12 non-collinear directions were used to obtain diffusion and estimate the tensor ( $p < 0.001 \rightarrow T = 3.505$ ); a T2 image was also acquired after this sequence. Anisotropic image reconstruction was made using the Diffusion Toolbox FMRIB (FDT) (Behrens et al., 2003). A brain extraction tool (BET) imaging mask was applied (Smith, 2002) and FA was gathered. Next, images generated by FA were normalized using the template FNIRT toolbox Tract-Based Spatial Statistics (TBSS) (Smith et al., 2006).

## RESULTS

### New software-based SMT: Conceptual and procedural advances

The SMT is based on the premise that social memory is a concept that only makes sense as we add to the encoding-recollection structure more than human-like figures; we add intentional mediation of the avatars' identity, because we understand that social memory is beyond memory for faces. That is, the capacity to intentionally interact with the characters in the process of constructing their identities is crucial for establishing a relationship between the subject and the human figure in the test. A second idea was to define few very important social metadata so that subjects could establish some sort of social bond with the avatars and also have intentionally defined inputs to recollect in the next phase. In this sense, before entering in the recollection phase, the participants have to name and define a profession (from a set of four) to each of the avatars. Through this procedure, we warrant the inclusion of one of the most important features of social cognition: its intentional structure. In that sense, our test is not only the first to introduce the idea of social memory, but also the first working memory test to actually mimic the vast majority of recollection procedures in real life, which involve remembering intentionally selected and organized information.

### Validation

First thing that we investigated is whether SMT is sensitive to difference in recollection in two different populations known to have different social cognition performances; normal adults and schizophrenic patients. Next, we evaluated how this difference relates to

performance in other social and cognitive tests. Subsequently, the internal consistence of the instrument was evaluated; the Cronbach's alpha and the correlation matrices for all items of each test were calculated. After, a factorial analysis was made using, Principal Component Analysis, in which we considered factors with the ability to explain over 80% of the variability. Then, the factorial weights of each item were obtained; lastly, we used Varimax rotation in order to facilitate data interpretation. The statistical analysis was made using raw data from each test, except for WASI, in which the sum of the pondered score from each subtest was used. All tests were double-tailed and the level of significance was set at 95%. Statistical analysis was performed using the SPSS version 21. Only individuals who completed the study were included in the analysis.

### Intergroup comparison

Initially, in order to verify the existence of socio-demographical differences between groups, an independent sample t test was made comparing age and socioeconomic status, returning significant statistical differences on both samples: age ( $t = -10.664$  and  $p < 0.001$ ) and socio economic status ( $t = -7.817$  and  $p < 0.001$ ). Then, a multivariate analysis of covariance (MANCOVA) was applied, comparing each group performance on all tests controlling their results by socioeconomic status and age covariates. The analysis showed multivariate differences between groups ( $F(1.197) = 20.961$ ,  $p < 0.001$ ; Pillai's trace = 0.415; Partial  $\eta^2 = 0.415$ ). The results for each test are presented on Table 2.

### Correlations with neuropsychological battery

In order to compare the SMT scores on each of its phases to the neuropsychological battery, a correlation matrix was made. The results are presented on Table 3. Rey's Complex Figure test showed substantial correlations between SMT in all groups, distinctively, higher correlations between the "Human" phase of SMT than its "Zombie" phase, on both recall and copy phases, except for recall phase on patients group, where this pattern was inverted. Also, Rey Complex Figure (RCF) recall phase presented higher correlations with SMT than its copy phase. Baron Cohen's Faux pas test presented significant correlations with "Zombie" phase of SMT in all groups, highlighting the patients group where the correlation between SMT and Faux pas was higher on "Human" phase. WASI correlates with SMT on all groups where the correlation is higher with the human phase on control and patients group. Distinctly, human phase relates to Faux pas and Zombie phase relates to RCF recall phase.

**Table 2.** Intergroup differences.

Test	EMM <sup>a</sup> adult	EMM <sup>b</sup> patient	F	Sig.	Partial Eta <sup>2</sup>
SMT H	15.45±0.33	11.42±0.68	21.924	<0.001	0.103
SMT Z	14.14±0.34	9.77±0.70	24.261	<0.001	0.113
FauxPas	57.88±0.65	43.71±1.32	72.643	<0.001	0.276
RCF (C)	34.88±0.34	28.429±0.69	55.030	<0.001	0.224
RCF (R)	23.01±0.50	13.58±1.03	52.884	<0.001	0.217
WASI	117.21±1.65	82.18±3.35	58.612	<0.001	0.264

<sup>a</sup>Estimated marginal means. <sup>b</sup>The F tests the between group effect. Controls (n=150) and patients with schizophrenia (n=50).

**Table 3.** Correlation of SMT between each phase of SMT, faux pas, RCF and WASI on each group, and phase.

Parameter	SMT	Faux pas	RCF (C)	RCF (R)	WASI
Controls n=150	Human	r=0.002*	r=0.127*	r=0.224*	r=0.288*
	Zombie	r=0.131*	r=0.070*	r=0.122*	r=0.152*
Patients n=50	Human	r=0.377*	r=0.186*	r=0.356*	r=0.215*
	Zombie	r=0.258*	r=0.155*	r=0.520*	r=0.160*

"Human" applies for the sum of the scores on human phase of SMT and "Zombie" for the sum at zombie phase. \* All results were significant (p<0.05).

### Internal consistency

The Cronbach's Alpha was calculated, resulting on 0.59 for the control group and 0.73 for the schizophrenic patients group. The correlation between each phase and their respective items were calculated, resulting on moderate correlation between phases on the patient group (0.47) and a correlation index of 0.31 on the adult group. Moderate to high correlation (> 0.5) between each phase's total and their corresponding leader recalling score was found on both groups (control: H=0.59, Z=0.64 and patient: H=0.79, Z=0.73).

### Factor analysis

Factor analysis showed strong evidences that SMT evaluates two separate factors, one related to the zombie phase and the other to the human phase. This tendency was verified by Principal Component Analysis and factorial charges matrices after varimax rotation for all groups (control = 82% and patient= 88%).

### Test sensitivity, specificity and predictive values

A receiver operating curve was traced for both versions of SMT using non-parametric methods for analyzing its

sensitivity and specificity on distinguishing schizophrenic patients and controls. The calculated area under the curve was C = 0.845 with standard error = 0.32, 95% confidence interval from 0.782 and 0.908 for the human version of SMT, C = 0.863 with standard error = 0.29, and 95% confidence interval from 0.806 and 0.920 for the zombie version of the test (Figure 3). Observing the results, we defined the cut off points that showed the best sensitivity and specificity, 13.5 for the human phase and 12.5 for the zombie phase, and separated the individuals on both groups according to it. Next, using the cross tabulation of these results and between patients and controls, the sensitivity (Se), specificity (Sp), positive (Pos) and negative (Neg) predictive values were calculated. On the human phase, the results were: Se= 0.745, Sp = 0.89, Pos = 0.569 and Neg = 0.786; and on the zombie phase the results were Se = 0.80, Sp = 0.786, Pos = 0.586 and Neg0.912.

### Brain correlates of sensitivity to human figures in the SMT

Findings regarding DTI were aligned with our hypothesis: a positive association between the fraction anisotropy at Heschl's gyrus and performance in SMT (r = 0.519, p<0.0066) (Figure 4). Heschl's gyrus mask was obtained from the automated anatomical labeling (Tzourio-Mazoyer et al., 2002). The fractional anisotropy was averaged inside the mask, and correlated with SMT.

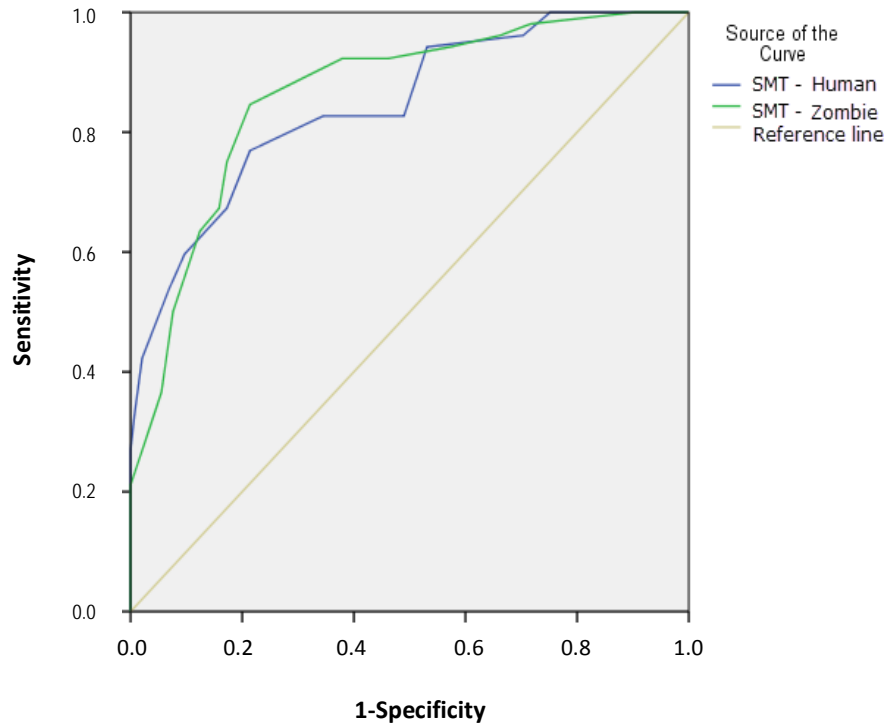


Figure 3. ROC curve of SMT. Diagonal segments are produced by ties.

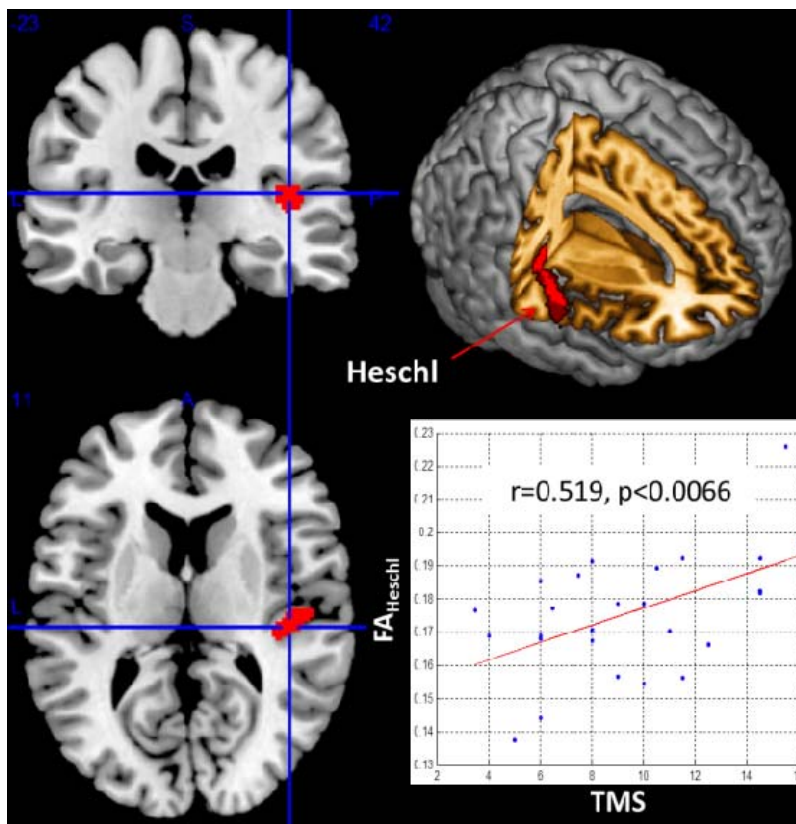


Figure 4. Heschl's gyrus anisotropy, positively correlated with performance in the clinical population.



## DISCUSSION

This study introduced the hypothesis of the existence of a previously unmapped cognitive dimension, a new software-based test that proposes to capture such trend, a neuropsychological battery aiming at advancing the validation of the new test and, last but not least, data on neural correlates of performance of a clinical population traditionally known for having social cognitive deficits, using DTI. As described by Urbina (2007), the validation process complies with the construct validation criteria, which involves evidences from its content, divergence, convergence patterns and related criterion, aspects which will be explained with details below.

From its conception, SMT's ecological validity is a major concern, simulating a daily life condition where the individual has to memorize and quickly recall a person's name, group and his position on a pre-established hierarchy. To our knowledge, SMT is the first instrument to quantify social memory apart from regular memory, presenting a new instrument in the row of social intelligence investigation field. SMT has high internal consistency, with Cronbach's alpha superior to 0.7 schizophrenic patients group and a little lower result for the control group. Also, its correlation matrix presented moderate to high correlations between items. Factorial analysis results corroborates with the hypothesized model, consisting on two distinct factors: social memory and regular memory. Also, intergroup comparison showed that SMT could discriminate correctly between normal control and individuals suffering with schizophrenia, along with other well established instruments.

The neuropsychological battery that was applied along with the new test had mainly pure cognitive and socio-cognitive tests. A first look on the relation matrix comparing SMT and these tests tells that it has characteristics of a visuo-spatial memory test, since its highest correlations are with RCF recall phase, a exhaustively explored visuo-spatial memory test, also, it is possible to observe its relation with social cognition, by its relation with faux pas, and intelligence, for its correlation with WASI. Taking a second look at the results, it is observable that SMT has higher correlations with patients group, indicating that SMT may be more sensitive to populations with impaired cognitive or sociocognitive functions. For instance, as predicted, patients had higher correlation with SMT's "Zombie" phase and RCF recall phase than SMT's "Human" phase with the same test; and a higher correlation between Faux Pas and SMT's "Human" phase rather than SMT's "Zombie" with the same test. Also, SMT's Cronbach's alpha is higher for patients, rather than controls.

Another important aspect is its correlation with WASI and the SMT's "Human" phase which is higher than its correlation with SMT's "Zombie" phase. This pattern is observed on both groups and is more prominent on the

control group, complying with the perspective described on the literature in which social interactions are mediated by individual heuristics in which intention, function among other aspects are fundamental and rationally managed. When this information is not or only partially available, as on SMT's "Zombie" phase, other aspects of social cognition, which are more intuitive take place, therefore, on individuals where cognitive functions are impaired, the intuition seems to have a greater role. All these aspects gathered together comprise a recollection of evidences which qualifies SMT as a validated neuropsychological instrument.

DTI analysis showed significant correlation between performance and Heschl's gyrus (BA41) anisotropy. This area, also known as transverse temporal gyrus, has been engaged in social cognition many times and is affected by schizophrenia (Kasai et al., 2003). Moreover, it has a simultaneous role in auditory and visual processing (Caclin and Fonlupt, 2006) and a role in semantic processing (Leff et al., 2009), which are in line with the structure of the test, which is about the ability of recollecting intentionally defined social clues, as previously defined. In an interesting paper, Fitch et al. (2010) suggested an evolutionary tie between language and social cognition, which could explain the role of some brain areas in both, as it applies to the Heschl's gyrus and the deep structure of our new neuropsychological test.

## Conclusion

Limitations regarding this study are: only DTI images were acquired which limits the analysis to structural connectivity. Encoding, storing and recalling social information warrants evaluation using a functional neuroimaging paradigm. When building the neuropsychological battery, we selected tests which were closely related to social memory, nevertheless, social intelligence is a multifactorial construct and may have other correlated functions, such as inhibitory control and mental flexibility. Neuro imaging was made on the clinical group, but not on the control group. Finally, schizophrenia spectrum has a wide variability, including not only social impairments, but other cognitive deficits that may blur the knowledge in which extent difference of performance may be specifically attributed to social memory.

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## Conflicts of interest

The authors declare that they have no conflicts of interest.

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