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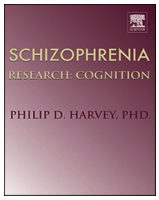

Research Paper

Embedded figures in schizophrenia: A main deficit but no specificity

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ABSTRACT

Visual deficits are core deficits of schizophrenia. Classically, deficits are determined with demanding psychophysical tasks requiring fine-grained spatial or temporal resolution. Less is known about holistic processing. Here, we employed the Leuven Embedded Figures Test (L-EFT) measuring classic aspects of Gestalt processing. A target shape is embedded in a context and observers have to detect as quickly as possible in which display the target is embedded. Targets vary in closure, symmetry, complexity, and good continuation. In all conditions, schizophrenia patients had longer RTs compared to controls and depressive patients and to a lesser extent compared to their siblings. There was no interaction suggesting that, once the main deficit of schizophrenia patients is discarded, there are no further deficits in Gestalt perception between the groups. This result is in line with a growing line of research showing that when schizophrenia patients are given sufficient time to accomplish the task, they perform as well as controls.

1. Introduction

Visual deficits are core deficits of schizophrenia. For example, schizophrenia patients describe the world often as distorted and fragmented (Giersch, 2019; Jordan, 1995). However, not all visual functions are deficient. In many paradigms, schizophrenia patients perform worse compared to healthy controls. There are other paradigms where they show no deficits (Lauffs et al., 2016; Grzeczkowski et al., 2018). There is no clear pattern why certain visual functions are deficient and others are not. For example, in contextual modulation, the perception of spatial illusions is comparable to controls (Grzeczkowski et al., 2018; Kaliuzhna et al., 2019; King et al., 2017). Prodromal patients show even improved performance in texture discrimination (Parnas et al., 2001; Knight et al., 2000). On the other hand, schizophrenia patients show weaker surround suppression (i.e., patients are less influenced by the context). However, this result holds true only for size and contrast but not for luminance and orientation (Dakin et al., 2005; Tibber et al., 2013). It must be mentioned that even within one paradigm, results are often mixed, i.e., different studies come to different conclusions, which may depend on differences in the set up or may be due to the often small sample sizes and the high degree of heterogeneity within the patient population.

It is important to determine whether deficits are of general or specific nature. For example, in a crowding study, patients perform worse in all conditions, i.e., no feature-specific effects are found arguing for a general visual processing deficit and not for a crowding specific one (Roinishvili et al., 2015). On the other hand, in visual backward masking deficits are quite specific, i.e., deficits occur only in certain conditions allowing to pinpoint deficits in a specific manner (Chkonia et al., 2010; Herzog et al., 2004).

In most visual paradigms (except for the illusion studies), the task is usually demanding, depending on fine-grained spatial information and/or subtle, low luminance differences. All these paradigms miss holistic processing, related to Gestalt processing. In the traditional EFT, observers have to locate the outline of the target. The target consists only of closed shapes (Witkin, 1950). Schizophrenia patients and at-risk observers for psychosis show poorer performance in EFTs compared to controls (Panton et al., 2016), whereas observers with autistic traits and diagnosed autism (Muth et al., 2014; Cribb et al., 2016) show superior

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performance for both reaction times and accuracy. The Gestalt principles of proximity and collinearity are intact in schizophrenia patients (Chey and Holzman, 1997). Only one study investigates the performance of depressive patients and find that depressive patients perform worse than individuals with autism, potentially at the level of schizophrenia patients (Bölte et al., 2007). However, the focus of the latter study is on autism and there are no clear pairwise group comparisons.

Here, we tested Gestalt perception using the Leuven Embedded Figures Test (L-EFT). The L-EFT is a computerized test to assess local versus global information processing based on how well participants can handle the embeddedness of local target shapes into global line patterns (de-Wit et al., 2017). Specifically, a local target shape is embedded in a global context pattern and observers must detect as quickly as possible, in which out of three displays the target is embedded (Fig. 1). The L-EFT is a three-alternative forced choice task, which includes closure, symmetry and complexity as properties of the target shape, as well as good continuation between target and context. Displays therefore vary in how easily the target can be segmented from the context, depending on four dimensions: 1) closure: *target open* versus *closed*; 2) symmetry: *present or absent*, 3) complexity: *the number of lines making up the target*, and 4) degree of embeddedness in terms of good continuation: *the number of target lines that are continued with the context*. Previous studies with the L-EFT in healthy students show that particularly good continuation and, to a lesser extent, symmetry influence perceptual grouping in the general population (de-Wit et al., 2017). No effect of closure on perceptual grouping is found (de-Wit et al., 2017).

The goal of this study is two-fold. First, we wanted to know whether schizophrenia patients show selective deficits or a general deficit for Gestalt principles. Second, we tested whether Gestalt processing deficits are endophenotypes of schizophrenia reflecting state rather than trait abnormalities (Gottesman and Gould, 2003). For an endophenotype, healthy siblings must show similar but attenuated deficits compared to their affected relatives. In addition, schizophrenia and depression show a substantial genetic overlap (Lee et al., 2013). In visual tasks, we find that depressive patients perform better than schizophrenia patients, although the electrophysiological correlates are reduced for both populations (Favrod et al., 2019). Both disorders often occur together to various degrees and are therefore not that easy to disentangle in clinical practice. For this reason, we compared the performance of the four populations (schizophrenia patients, their siblings, patients with depression, and healthy controls) with the L-EFT.

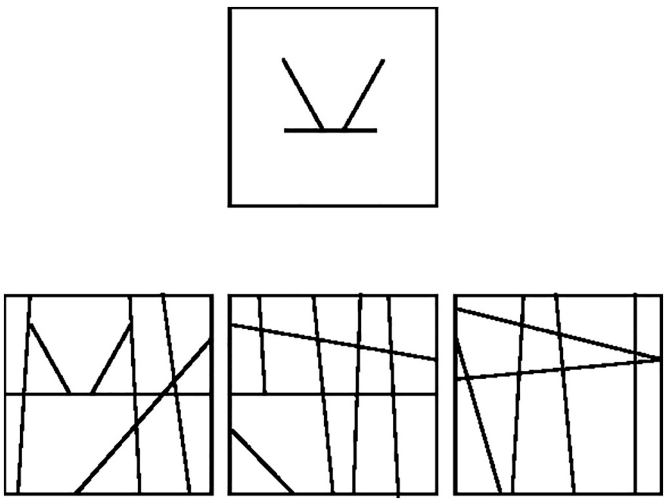

Fig. 1. Stimuli display. The upper square contains the target figure, and the three lower squares show three possible contexts, of which only one contains the target. Here, the target figure is embedded in the left square. The example is of intermediate difficulty as only one line (out of three lines) is connected with the contextual lines. Adapted from de-Wit et al. (2017), with permission.

2. Methods

2.1. Stimuli and task

Stimuli and task are similar to those described in Huygelier et al. (2018). There were 16 target figures embedded in a context figure. The targets were composed of either 3, 4, 6, or 8 lines and could be either open or closed shapes, and either symmetric or non-symmetric shapes (Fig. 2). The targets were embedded in the context in 4 different ways. The number of lines of the target connected with the context varied between 0 (very easy) and all lines (very difficult). Fig. 3 shows an example of the three embeddedness levels for an octagon target. In total, there were 64 trials randomly presented: 16 targets × 4 embeddedness levels. Out of the 64 trials, 16 targets were symmetric and open, 16 were symmetric and closed, 16 were asymmetric and open, and 16 were asymmetric and closed. Regarding complexity, there were 16 trials for each condition (i.e., 3, 4, 6 and 8 target lines). The target was presented in one out of three displays and participants chose the display with the target figure as quickly and as accurately as possible by using the computer mouse. For incorrect responses, participants received a visual error feedback (a red square surrounding the incorrect alternative) and were asked to choose one of the two remaining displays. Displays lasted until the correct response was chosen. Then, participants pressed the escape bar to proceed to the next trial. Stimulus presentation and response registration were controlled using a software developed in Visual Studio (Huygelier et al., 2018).

2.2. Data analysis

Only the first response to each display was used, i.e., in case of incorrect responses, the second choice was not considered. Performance was calculated as the proportion of correct responses and the median response time for each participant. At the participant level, modified z-score transformations (with median and median absolute deviation, instead of mean and standard deviation) were applied to reduce the impact of outliers (Iglewicz and Hoaglin, 1993). Out of the 155 participants, 63 showed z-score RTs greater than 3.5 for on average 2 trials (out of 64, max. 6 trials), which is rather low. For this reason, all raw data was considered in the analysis with neither corrections nor rejections. In the Supplementary material section S1, the average number of responses is provided, as well as the entire amount of time taken to

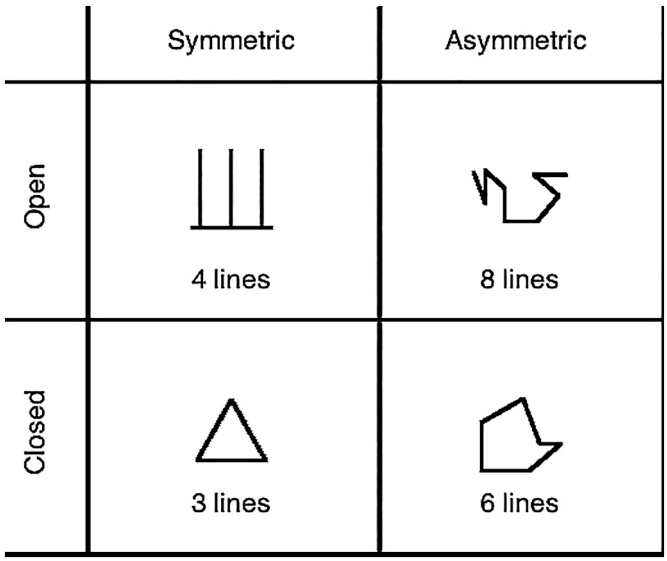

Fig. 2. Target characteristics. Examples of 4 targets (out of 16). The targets varied in the number of lines (3, 4, 6, and 8), symmetry, and closure. Adapted from de-Wit et al. (2017), with permission.

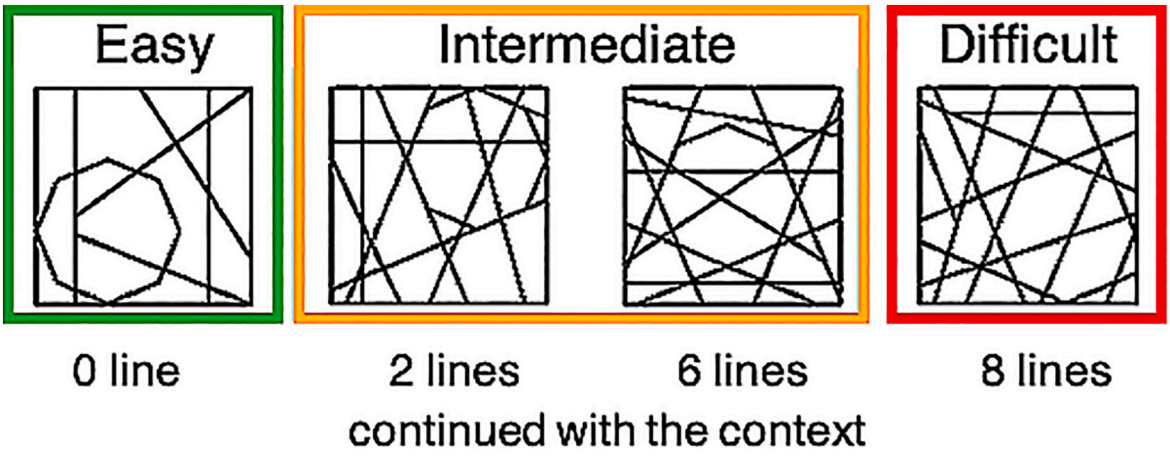

Fig. 3. Levels of embeddedness. The target shape here is an octagon. In the easy condition, no line is connected with the context. In the intermediate difficulty level displays, 2 or 6 lines of the octagon target are connected with the context. In the difficult condition, all lines are connected with the context. Adapted from de-Wit et al. (2017), with permission.

complete one trial, which yielded almost similar results (schizophrenia patients were slower compared to all groups but their siblings).

All data were processed in Matlab (R2018b). The JASP software (v.0.9.1) was used to conduct statistical analyses. We first computed ANOVAs, which are relatively robust to normality violations (Lix et al., 1996) and *t*-tests for post-hoc comparisons. Second, for comparison purposes and because RTs distributions were a bit skewed, Kruskal-Wallis and Friedman tests (the non-parametric ANOVA and t-test equivalents) were also computed and are reported in the Supplementary material section S2–S6. Both types of tests yielded similar results, with one exception mentioned in the Discussion. We computed four independent repeated measures ANOVAs, one for each feature (i.e., closure, symmetry, complexity, and embeddedness), instead of a 5-ways ANOVA (i.e., group × closure × symmetry × complexity × embeddedness) because of the nested design (e.g., a wrong response at the first response leads to a loss of the entire level data of the participants; in the difficult embeddedness condition, these are more than 50%, reflecting that the condition is indeed difficult). We also computed a Linear Mixed Model (see Supplementary material section S10), with again similar results.

2.3. Participants

Forty-seven patients with schizophrenia (SZ), 25 relatives (mostly siblings; SB) with no history of psychosis, 28 patients with depression (DP), and 55 controls (CL) took part in the experiment. All participants had normal or corrected-to-normal vision, with visual acuity superior or equal to 0.8 as determined for both eyes with the FrAct (Bach, 1996). All participants signed informed consent and were informed that they could quit the experiment at any time. Procedures complied with the Declaration of Helsinki (except for pre-registration) and were approved by the local ethics committee. General exclusion criteria were drug or alcohol abuse, neurological or other somatic illnesses influencing the participants' mental state.

Patients and siblings were recruited either from the Tbilisi Mental Health Hospital or from the Acute Psychiatric Departments of Multiprofile Clinics. Patients were diagnosed with schizophrenia or major depressive affective disorder according to the Diagnostic and Statistical Manual of Mental Disorders IV/5 (DSM) by means of an interview based on the Structured Clinical Interview, information of the staff, and the study of the records. Psychopathology was assessed by an experienced psychiatrist (EC) with the Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962) and the Hamilton Depression Rating Scale with 17-items (HDRS; Hamilton, 1960; Bagby et al., 2004) in depressive patients and with the Scales for the Assessment of Negative (SANS; Andreasen, 1984a) and Positive (SAPS; Andreasen, 1984b) Symptoms in schizophrenia patients. Apart from 3 patients, all schizophrenia patients were treated with antipsychotics (clozapine, levomepromazine, haloperidol, zuclopentixol, risperidone, olanzapine, fluphenazine, amisulprid, chlorprothixen, trifluoperazine, or quetiapine). Depressive patients received antidepressants (fluoxetine, fluvoxamine, clomipramine, venlafaxine, escitalopram, or trazodone). Some depressive patients also took neuroleptics (quetiapine, olanzapine, risperidone, or clozapine) as adjunctive medication. Schizophrenia patients participated in the study when they had sufficiently recovered from an acute episode. Depressive patients were recovering from depression and were tested when stabilized. At the time of testing, depressive patients suffered from a mild or moderate depressive syndrome (mean 16.57 ± 5.73). Seventeen is the cut-off point between mild and moderate depression according to the 17-items HDRS. The HDRS has a reliability of 0.46 to 0.97 for internal reliability, 0.82 to 0.98 for inter-rater reliability, and 0.81 to 0.98 for test–retest reliability (Bagby et al., 2004). However, validity is under discussion because of the changes of the DSM (Bagby et al., 2004). We used the scale only to determine the severity of the depressive syndromes at the time of testing.

Apart from one relative, all were siblings of a patient, while one was a parent of a patient (for this reason we call the group siblings). Only 11 siblings were related to a patient included in the schizophrenia group. The rest had a sibling with schizophrenia not included in this sample. Healthy controls were recruited from the general population. Demographics are shown in Table 1.

Depressive and schizophrenia patients were free from another axis I disorder. Siblings and controls were free from axis I disorders at all. Family history of psychosis was an exclusion criterion for the controls while the sibling group had no history of psychoses.

3. Results

Performance range was 62.5–100% ($\mu = 81.5\%$, $\sigma = 0.07$). Chance level was 33%. There was a trend towards a main effect of group for accuracy ($F(3,151) = 2.634$, $p = 0.052$, $\eta^2 = 0.050$, Fig. 4, left). For details see the Supplementary material S1.

There was a main effect of group for RTs ($F(3,151) = 9.557$, $p < 0.001$, $\eta^2 = 0.160$) with schizophrenia patients being significantly slower than controls ($p < 0.001$, $d = 1.003$), depressive patients ($p = 0.004$, $d = 0.724$), and siblings ($p = 0.046$, $d = 0.537$, Fig. 4, right). p-Values for post-hoc comparisons are Bonferroni-corrected and shown in the Supplementary material section S2 as well as the non-parametric Kruskal-Wallis test.

First, there was a main effect of closure considering the entire sample of all four groups ($F(1,151) = 6.652$, $p = 0.011$, $\eta^2 = 0.041$), with closed

Table 1
Demographics.

	Controls	Siblings	Schizophrenia	Depression	Statistics
N	55	25	47	28	
Gender (F/M)	28/27	15/10	9/38	18/10	$X^2(3) = 19.93$, $p < 0.001$
Age (mean ± SD)	38.05 ± 8.93	37.64 ± 10.07	39.00 ± 8.33	34.64 ± 10.43	$F(3,151) = 1.361$, $p = 0.257$
Education (mean ± SD)	15.58 ± 2.77	13.96 ± 2.54	13.44 ± 2.28	14.71 ± 2.40	$F(3,151) = 6.596$, $p < 0.001$
Illness duration (mean ± SD)			13.43 ± 7.97	7.26 ± 6.16	$t(73) = 3.513$, $p < 0.001$
SANS (mean ± SD)			9.98 ± 5.19		
SAPS (mean ± SD)			9.04 ± 3.09		
BPRS (mean ± SD)				32.54 ± 7.08	
Hamilton (mean ± SD)				16.57 ± 5.73	
CPZ equivalent (mean ± SD)			604.6 ± 403.6[a]	236.9 ± 282.4[a]	$t(63) = 3.753$, $p < 0.001$
Handedness (R/L)	52/3	25/0	46/1	27/1	$X^2(3) = 1.901$, $p = 0.593$
Visual acuity (mean ± SD)	1.65 ± 0.43	1.48 ± 0.45	1.34 ± 0.41	1.43 ± 0.44	$F(3,151) = 4.600$, $p = 0.004$

[a] 44 out of 47 schizophrenia patients and 21 out of 28 depressive patients were medicated.

targets leading to shorter RTs compared to open targets (Fig. 5, upper left). There was a main effect of group ($F(3,151) = 8.713$, $p < 0.001$, $\eta^2 = 0.148$) with schizophrenia patients showing the slowest RTs. There was no interaction. p-Values for post-hoc tests and corresponding non-parametric tests are reported in the Supplementary material section S3.

Second, there was no significant main effect of symmetry considering all four groups ($F(1,151) = 2.221$, $p = 0.138$, $\eta^2 = 0.014$). There was a main effect of group ($F(3,151) = 10.06$, $p < 0.001$, $\eta^2 = 0.167$) with schizophrenia patients showing the slowest RTs. There was no interaction (Fig. 5, upper right). Supplementary statistical tests are shown in the Supplementary material section S4.

Third, there was a main effect of complexity across the four groups ($F(2.543,384.034) = 9.200$, $p < 0.001$, $\eta^2 = 0.057$), where more lines generally lead to longer RTs, with the exception of targets composed of three lines compared to four (Fig. 5, bottom). There was a main effect of group ($F(3,151) = 8.474$, $p < 0.001$, $\eta^2 = 0.144$) with schizophrenia patients showing the slowest RTs. There was no interaction. For supplemental tests, see Supplementary material section S5.

Finally, there was a main effect of embeddedness considering all participants ($F(1.139, 171.985) = 293.719$, $p < 0.001$, $\eta^2 = 0.656$, Fig. 6). There was a main effect of group ($F(3,151) = 5.457$, $p = 0.001$, $\eta^2 = 0.098$). There was no significant interaction between the group and the level of embeddedness ($F(3.417,171.985) = 0.969$, $p = 0.417$, $\eta^2 = 0.006$), Greenhouse-Geisser corrected. For supplemental tests, see Supplementary material section S6.

4. Discussion

Schizophrenia is a heterogenous disease strongly influenced by genetic and environmental factors (Sullivan et al., 2003). To cope with this complexity, it is crucial to understand which functions are abnormal and which are intact. In this respect, it is essential to publish null results to avoid the impression that patients are deficient in almost all paradigms (given that patients usually do not show superior functioning compared to controls). For abnormal functions, it is important to determine whether deficits are specific or rather unspecific, such as general slowing down, diminished attention, or a reduction of processing capacity (Silverstein et al., 2010; Uhlhaas and Silverstein, 2003).

Here, we investigated Gestalt processing in schizophrenia patients, their relatives, depressive patients, and unaffected controls. Reaction times revealed group performance differences, whereas differences in accuracy were only marginally significant ($p = 0.052$, $\eta^2 = 0.050$). For almost all features, schizophrenia patients were slower compared to all the other groups (i.e., controls, depressive patients and their siblings) with two exceptions: (a) complexity, where schizophrenia patients were slower compared to controls and depressive patients but not the siblings ($p = 0.056$) and (b) good continuation, where only schizophrenia patients and controls differed significantly. Importantly, siblings performed almost at the level of controls in all conditions, which speaks against an endophenotype of schizophrenia (Gottesman and Gould, 2003).

The interaction (group × feature) was never significant, suggesting

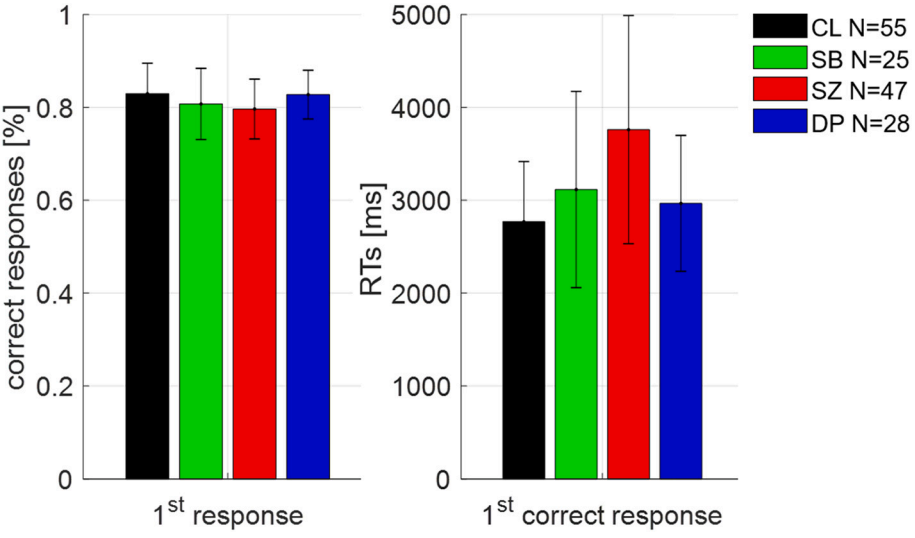

Fig. 4. Accuracies (left) and RTs (right) for the first response (black: controls, green: siblings, red: schizophrenia patients and blue: depressive patients). Only a trend was found for accuracy ($p = 0.052$) whereas RTs differed significantly with schizophrenia patients showing the slowest responses. Overall, schizophrenia patients showed the slowest response and the worst accuracy, followed by their siblings, then the depressive patients and finally the healthy controls with the fastest response and the best accuracy.

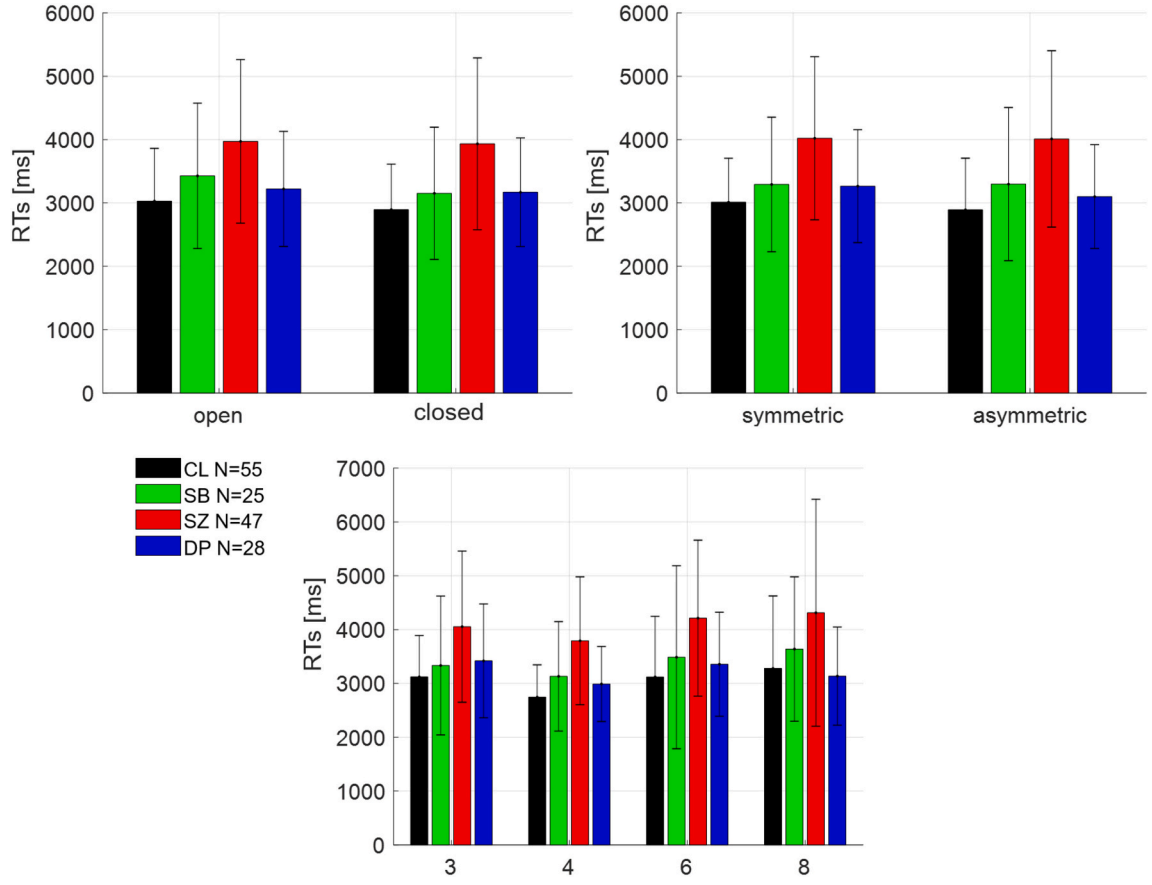

Fig. 5. RTs. Upper left: Closed targets lead to shorter RTs as compared to open targets. Upper right: No effect of symmetry was found. Bottom: Complex targets (e.g., composed of 8 lines) needed longer RTs as compared to less complex targets (e.g., 4 lines), except for targets composed of 3 lines. For all three features (closure, symmetry and complexity), schizophrenia patients showed longer RTs compared to the other three groups (controls, siblings and depressive patients). Comparisons of patients and siblings were significant for closure ($p_{bonf} = 0.049$) and marginally significant for complexity ($p_{bonf} = 0.056$).

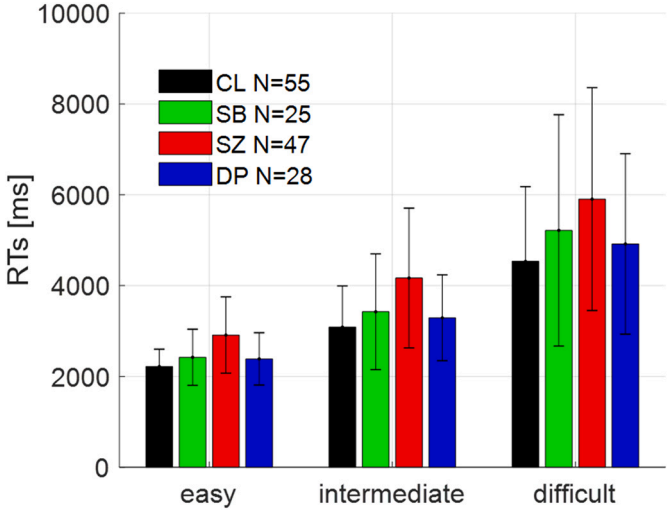

Fig. 6. RTs for target embeddedness. The easy and difficult conditions contain a maximum of 16 trials per participant while the intermediate condition contains a maximum of 32 trials per participant because we pooled two levels. First, RTs were longer for the difficult level as compared to intermediate or low levels. Second, schizophrenia patients were slower compared to controls only.

that all features were processed similarly across group (except for the main effect of group). Therefore, it seems there is a general deficit of schizophrenia patients but there is no evidence for specific Gestalt processing differences between the different populations (except for the difficult level of embeddedness, see section S10 of Supplementary material). The unspecific deficit may be explained by a generally slowed processing, or capacity deficits. As shown in a masking paradigm, provided that schizophrenia patients are given enough time (i.e., long inter-stimulus intervals), they are able to perform as well as controls do with shorter inter-stimulus intervals (Plomp et al., 2013).

Our results are in line with a meta-analysis indicating that schizophrenia patients are slower to extract the target from the context compared to controls (Panton et al., 2016). There was a larger inter-observer variability in schizophrenia patients as compared to the other populations (see RT distributions in the Supplementary material section S7). This higher variance is likely the reason why there are sometimes mixed results in the literature (King et al., 2017).

Depressive patients performed better than schizophrenia patients for all features (closure: $d = 0.255$, symmetry: $d = 0.279$ and complexity: $d = 0.273$) except good continuity (level of embeddedness). This result is contradictory to one study which showed that depressive patients were at the level of schizophrenia patients (Bölte et al., 2007). In addition, Bölte et al. showed that depressive patients were performing worse than people with autism (note: there was no direct comparison to controls). Here, we failed to find a significant difference between controls and depressive patients. In section S8 of the Supplementary material, we provide a Bayesian analysis (BF) for good continuation, which is the most important feature of the EFT. We found almost no evidence for performance differences between depressive patients and controls ($BF_{10} = 0.344$).

Importantly, we did not find a significant effect between siblings and

controls, indicating that the processes involved in the L-EFT are likely not an endophenotype (Gottesman and Gould, 2003). Absence of proof is not proof of absence, but with p-values close to 1 and effect sizes close to 0, there is evidence for the null hypothesis (i.e., no effect). In addition, the Bayesian analysis of section S8 of the Supplementary material revealed a BF_{10} inferior to 1/3.

Good continuation (level of embeddedness) and complexity (number of lines) influenced performance in healthy students more strongly than closure and symmetry (de-Wit et al., 2017). Importantly, symmetry and complexity mainly depended on the interaction with good continuation. Here, we found that good continuation, closure, and complexity affected performance but not symmetry (though with the non-parametric analysis and in the Linear Mixed Model, there was an effect of symmetry). In any case, the effect is smaller as compared to closure, complexity or embeddedness. Importantly, all effects of de-Wit et al. (2017) were found for RTs and accuracies, while in the current study, we mainly found effect for RTs. We might lack sensitivity for accuracy (and found only marginal differences) because our sample size is much smaller than in de-Wit et al. (2017), i.e., $n_{tot} = 155$ versus $n_{tot} = 443$, respectively.

A surprising result was that targets composed of 3 lines led to longer RTs than targets composed of 4 lines ($p_{bonf} < 0.001$). de-Wit et al. (2017) showed that complex shapes (with more lines) were easier to detect (higher accuracy) than less complex ones. They claimed that a complex shape is "a more unique occurrence in the embedding context, enhancing the likelihood of detection". Here, we only found that participants took more time to detect them. The measurement differences (accuracy versus RTs) can partly explain these discrepancies. Nonetheless, RTs findings were reported to be more reliable than accuracies (Panton et al., 2016).

This study suffers from limitations such as unbalanced sample sizes, which may lead to reduced power to detect effects. Gender imbalance in schizophrenia is also an issue as more male than female patients participated in the study. Gender differences in vision are often heterogenous and do not depend on a single mechanism (Shaqiri et al., 2018b). They are outside the scope of this study. In addition, patients were medicated and the inclusion criterion was rather broad. Medication is a potential cause for patient's slowness, though here CPZ equivalent and overall RTs did not correlate (see Supplementary material section S9). Regarding the other demographical differences, we decided to not include them as covariates to not compromise with statistical power, because we already have many variables in the specific design. For this reason, we just report them. Controls had longer education compared to patients. However, vision is largely independent of social/cultural differences and gender (Plomp et al., 2013; Shaqiri et al., 2018b). Illness duration was longer for schizophrenia patients as compared to patients with depression.

5. Concluding remarks

Overall, schizophrenia patients have no specific Gestalt processing deficit but a general processing deficit (e.g., longer RTs) that is likely due to the symptoms of the disease. Once accounted for, patients perform on the same level as other groups. For example, there was no interaction group × feature with the healthy controls. Similar null results (i.e., patients performing as well as controls) are shown with many other paradigms such as 1) out of body experience (Shaqiri et al., 2018a), 2) illusions (Grzeczkowski et al., 2018), 3) retinotopic integration (Lauffs et al., 2016), and 4) visual crowding (Roinishvili et al., 2015). In particular, schizophrenia patients have an impaired sense of agency in general but there is no evidence for abnormal body ownership (Shaqiri et al., 2018a) and patients show strong deficits in crowding as compared to controls, however, when discarding for the main effect, schizophrenia patients are not different from controls in all conditions. "Main effect" deficits are everywhere in schizophrenia research (visual masking, Herzog et al., 2013; auditory ERPs, Turetsky et al., 2009; cognitive working memory, Lee and Park, 2005). The L-EFT shows a similar main deficit.

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Declaration of competing interest

The authors declare that there is no conflict of interest.

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Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.scog.2021.100227.

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