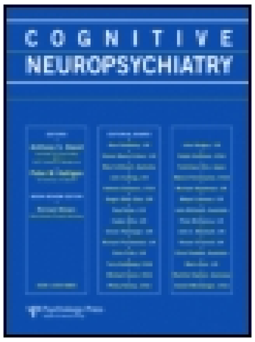

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Remediation of perceptual organisation in schizophrenia

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ABSTRACT

Introduction: Impaired perceptual organisation in schizophrenia has been repeatedly described in clinical and research literatures. It has also been associated with problems in more complex aspects of visual function, including visuospatial and visual cognitive test performance. Two therapeutic interventions were developed here that target perceptual organisation: (1) Computer-based training, which emphasized stimulus-driven processing (bottom-up approach), and (2) Instrumental Enrichment therapy, which is a therapist-guided interactive learning method (top-down approach).

Methods: Twenty-eight patients diagnosed with schizophrenia or schizoaffective disorder participated in a 12-week programme. For both forms of interventions, task difficulty increased progressively, based upon successful performance. The third group of patients, which served as controls, received a similar therapeutic intervention that did not include a perceptual organisation component. Before and after intervention, participants received tests of perceptual organisation, as well as a battery of neuropsychological tests.

Results: Results indicate that both forms of intervention improved perceptual organisation ability relative to the control condition. In addition, the improvement was found for select neuropsychological tests, although the pattern of improvement did not favour capacities more closely associated with visual organisational or visuospatial function.

Conclusions: Together, results demonstrate the effectiveness of new remediation protocols that target mid-level visual processing, which generalized to select visual cognitive functions.

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cognitive rehabilitation; perceptual grouping; training; visual impairment; Gestalt

Introduction

Perceptual organisation is a fundamental component of visual processing in which elements of visual images are segregated and combined into discrete object representations. Integration of stimulus components is based upon regularities in visual patterns, including spatial relationships and similarity among features (Sasaki, 2007; Seymour, Karnath, & Himmelbach, 2008). Perceptual organisation occurs at an intermediate level

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of visual processing and precedes higher-order visual functions. Dysfunction at the level of perceptual organisation may therefore impair other visual functions, including the recognition of faces and common objects, visual short-term memory, and the identification of facial emotions and complex visual scenes (Corjoukov et al., 2012; Curby, Goldstein, & Blacker, 2013; Rabinowicz, Opler, Owen, & Knight, 1996).

Numerous studies describe perceptual organisation impairment in schizophrenia (for reviews: Uhlhaas & Silverstein, 2005; Silverstein & Keane, 2011). Impaired perceptual organisation in schizophrenia has been found using a variety of task conditions and stimulus domains, including the integration of contours (Silverstein et al., 2006), perceptual grouping by proximity and colour similarity (Kurylo, Pasternak, Silipo, Javitts, & Butler, 2007), and the integration of visual motion cues (Chen, Bidwell, & Holzman, 2005). In addition, reduced function at the level of perceptual organisation has been associated with impairment in other perceptual and cognitive functions in schizophrenia. For example, perceptual organisation deficits in schizophrenia are related to impairments in constructing visual representations, such as faces from degraded stimuli (Joshua & Rossell, 2009; Silverstein et al., 2010; Silverstein et al., 2014), forming visual memory representations (Cocchi et al., 2007; Silverstein, Bakshi, Chapman, & Nowlis, 1998; Silverstein, Bakshi, Nuernberger, Carpinello, & Wilkniss, 2005), and facial emotion decoding (Turetsky et al., 2007), which are critical elements of social cognition and intact social functioning. Improvement at early and late stages of visual perceptual organisation by means of therapeutic interventions should thereby improve visual cognitive abilities, such as object and facial recognition, as well as complex aspects of visual function in schizophrenia, including reading, facial emotion recognition, and visual memory.

Therapies designed to improve cognitive function in schizophrenia include hierarchical training protocols. Specifically, these therapies present material systematically across levels of difficulty or complexity and have shown that training on basic sensory and perceptual functions leads to improvement of high-order cognitive functions and reduction of cognitive symptoms. In the auditory domain, training at the level of basic auditory processing has been shown to improve performance on auditory functions as well as more high-order cognitive abilities (Adcock et al., 2009; Fisher et al., 2015). Specifically, training on tasks such as discrimination of auditory frequency or synthesized speech components resulted in significant increases in speed of auditory processing as well as improved cognitive function, particularly for measures of verbal cognition, such as verbal working memory and verbal learning (Adcock et al., 2009, 2010). In the visual domain, training that targeted early visual processing has been found to affect performance on visual cognitive and social cognitive function in schizophrenia. Contreras, Tan, Lee, Castle, and Rossell (2018) compared effects of receiving either cognitive remediation training (CogPack) or cognitive training plus visual processing training, which included tasks associated with visual discrimination and perceptual organisation. Patients receiving the additional visual processing training showed higher rates of improvement on measures of visual learning, working memory, and social cognition. Surti, Corbera, Bell, and Wexler (2011) examined the effect of visual training on visual cognitive function in schizophrenia. Visual training that targeted stimulus feature and object identification was found to improve performance on visual-spatial memory. Results of these studies verify that training on visual and auditory processing can improve performance in schizophrenia and that improvement at a basic level of processing may generalize to higher perceptual and cognitive functions (Fisher et al., 2015; Surti & Wexler, 2012). These results validate the effectiveness of cognitive training that targets sensory processing in order to improve cognitive function in schizophrenia.

To date, remediation protocols in schizophrenia have not specifically addressed low-level or mid-level visual functions, such as perceptual organisation. To address this, two remediation protocols were developed that differed in training strategy. The first intervention was based on a visual discrimination task that focused on characteristics of the image, thereby emphasising stimulus-driven (bottom-up) processes. However, performance is not restricted solely to low-level processes, since higher-order functions such as attention and perceptual decision are necessary as stimuli approach threshold levels. Emphasis on bottom-up processes reflects the nature of the perceptual task, in which participants are exposed to repeated practice with discriminating stimulus patterns. The second intervention involved interactive learning which served to improve cognitive, perceptual, and problem-solving skills (top-down approach). This intervention is not restricted solely to top-down factors, however, as bottom-up processes are required for initial processing of the stimuli.

Computer training was based on a previously validated battery that demonstrated sensitivity to schizophrenia (Kurylo et al., 2007). With this battery, participants are trained on a visual discrimination task that requires perceptual grouping in order to disambiguate dot patterns. By engaging grouping processes during training, associations among stimulus components are strengthened, thereby increasing the efficiency of stimulus processing.

Instrumental Enrichment (IE) therapy consisted of training on two higher-order perceptual organisational tasks (Organization of Dots and Analytic Perception) within the Feuerstein IE cognitive training system (Feuerstein & Feuerstein, 1991; Feuerstein, Rand, Hoffman, & Miller, 1980; Feuerstein, Falik, & Feuerstein, 2010). This system employs paper and pencil-administered tasks designed to enhance deficient cognitive, perceptual, and problem-solving skills. IE utilises the didactic training strategy of Mediated Learning, which is a dynamic teaching/learning strategy by which the therapist facilitates an interactive learning experience designed to maximize the subject's estimated learning potential. IE is used as a cognitive remediation programme targeting deficient perceptual, attentional, linguistic, cognitive and metacognitive abilities (Feuerstein & Feuerstein, 1991; Feuerstein, Rand, Hoffman, Egozi, & Ben-Schachar, 1991; Feuerstein et al., 1980) IE therapy has been employed for several neurocognitively impaired populations including individuals diagnosed with Down syndrome, autism, dementia and acquired brain injury, but has not yet been used to target perceptual organisation in schizophrenia.

Participants underwent a 12-week period of the intervention of either computer-based training or IE therapy. A third subject group received a similar therapeutic intervention that did not include a perceptual organisation component. Perceptual organisation as well as other neuropsychological tests of visual and cognitive functions were assessed before and after the intervention period. Because perceptual organisation is a prerequisite for higher-order visual functions, it was hypothesised that benefits of training would generalize to other visual capacities related to perceptual organisation. Specifically, visual-spatial, visual memory, and visual discrimination functions that contain components of perceptual organisational were expected to improve following training.

Methods

Patients underwent a 12-week remediation protocol that involved either computer training, IE therapy, or a control condition that did not contain a perceptual organisation component. Patient recruitment, assessment, and intervention took place at the Cognitive and Vocational Rehabilitation Unit of the Manhattan Psychiatric Center (MPC). Assessment and intervention occurred with an eight-member research team comprised of a Research Coordinator (overseeing patient recruitment and intervention), a testing Evaluator (responsible for assessments), and six individuals responsible for intervention sessions. The intervention was conducted by undergraduate and graduate volunteers, under the supervision of the Research Coordinator.

Subjects

Candidates for the study were comprised of in-patients at MPC who met DSM-IV criteria for schizophrenia or schizoaffective disorders. Patients were free from cognitive deficits associated with disorders other than schizophrenia or schizoaffective disorder (including intellectual disability, dementia, or traumatic brain injury). In addition, patients did not show signs of persistent confusion or disorientation, excessive distractibility, or disruptive, agitated or violent behaviour. Participants provided written informed consent after procedures had been fully explained. Patients were assigned to one of three treatment groups (Table 1) which did not differ significantly in age ($F(2, 25) = 0.0006$, $p < .05$), age of onset ($F(2, 25) = 0.663$, $p < .05$), symptoms as rated using the Positive and Negative Syndrome Scale (PANSS) (Kay, Opler, & Fiszbein, 1987) ($F(2, 25) = .0006$, $p < .05$), or level of education ($F(2, 25) = 0.588$, $p < .05$). All participants were receiving medication at the time of the study, predominantly haloperidol or clozapine. Random assignment of patients to experimental condition enabled medication type and dosage to be distributed similarly across subject treatment groups. This research was performed with the approval of the Institutional Review Board of MPC.

Intervention 1: computer training

Patients assigned to the computer-based training group ($n = 11$) participated in 36 sessions. Subjects received three training sessions per week, for approximately 45 minutes per session. Training was performed separately for each of four-stimulus feature. For each feature, training proceeded for seven minutes. Following a brief break, the second block of trials was begun, using a different feature. The order of feature assignment was randomised for each session.

Table 1. Patient characteristics.

	Control Group	Computer Training	IE Therapy
N (M/F)	8 (7/1)	11 (10/1)	9 (7/2)
Age (years)	33.8 (4.8)	34.6 (9.0)	38.8 (11.6)
Estimated age of onset (years)	19.0 (10.8)	19.9 (2.8)	20.3 (3.3)
PANSS total	86.5 (5.8)	90.6 (19.0)	80.4 (9.2)
Education (years)	13.0 (1.3)	12.3 (1.4)	12.4 (2.1)

Stimulus features

Perceptual organisation was established by means of the Gestalt principle of similarity. Grouping by the similarity of basic stimulus features represents a fundamental principle of perceptual grouping associated with initial stages of visual processing (Han, Jiang, Mao, Humphreys, & Gu, 2005; Roelfsema & Houtkamp, 2011). Four stimulus features served as the grouping cue: luminance, colour, line orientation, and motion. These four stimulus features represent fundamental components of early visual processing (Van Essen, Anderson, & Felleman, 1992). Stimuli were composed of a grid of elements that subtended a 22° square field, presented briefly on a computer monitor. Stimuli could be perceptually organised as a series of parallel lines, oriented either vertically or horizontally.

Luminance. For the luminance condition, stimuli consisted of a 20×20 array of square elements. Stimulus elements were presented at two luminance levels (3.9 and 29.5 cd/m^2, Michelson contrast = 0.77) on a grey background (16.5 cd/m^2). Stimulus organisation was established by the similarity in luminance along either columns or rows (Figure 1(A)).

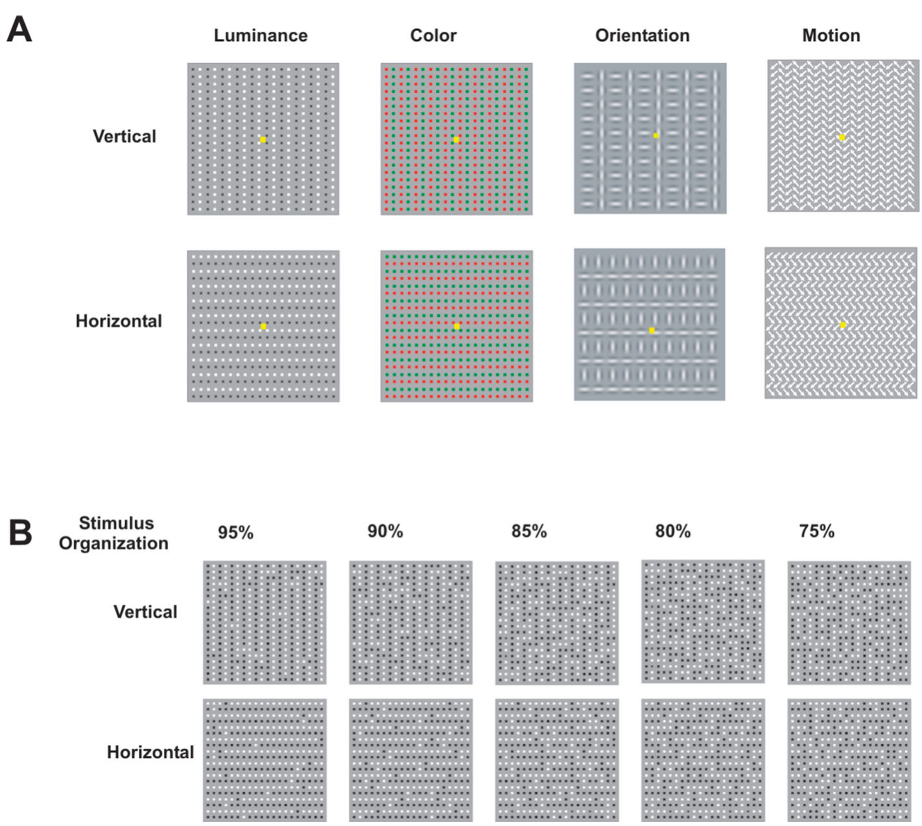

Figure 1. (A) Examples of the vertical and horizontal conditions for each of the four stimulus features: Luminance; Color; Gabor patch orientation; Motion direction. (For motion, arrows did not exist in stimuli, but are used here to indicate motion direction of solid square elements). (A) Examples of stimuli for the luminance condition across levels of stimulus disorganisation.

Color. For the colour condition, stimuli consisted of a 20 × 20 array of squares. Elements consisted of solid squares, 0.35° on a side and separated by 0.69°, that were either red (Commission Internationale de l'Eclairage uniform chromaticity scale (CIE-UCS) coordinates: $u' = 0.368$, $v' = 0.513$; luminance = 16.51 cd/m^2) or green (CIE-USC coordinates: $u' = 0.132$, $v' = 0.553$; luminance = 18.46 cd/m^2). Hue and saturation approximated isoluminance. For vertical grouping, each column contained elements of the same colour, alternating between colours across columns. For horizontal grouping, rows contained the same colour, alternating between colours down the rows (Figure 1(B)).

Orientation. For the orientation condition, stimuli consisted of a 10 × 10 array of Gabor elements, which modulated from 29.5 to 3.9 cd/m^2. All stimulus elements were of the same mean luminance. Patches were presented at a spatial frequency of 2.7 cycles/degree with a centre-to-centre separation of 0.72°, in which approximately 2.5 periods were visible. Elements were oriented either vertically or horizontally. Stimulus organisation was established by collinearity along alternating rows or columns (Figure 1(C)).

Motion. For the motion condition, stimuli consisted of a 20 × 20 array of square elements. The luminance of stimulus elements was 29.5 cd/m^2, presented on a grey background of 16.5 cd/m^2. Stimuli consisted of five consecutive frames, producing motion for 235 ms, at a rate of 4°/sec. The direction of displacement was selected from four possibilities (each a 45° path, either ↖, ↗, ↙, or ↘). Each stimulus contained two of the four possible motion directions, selected randomly on each trial. Stimulus organisation was established not by the actual movement direction, but by the similarity in diagonal motion that occurred among dots along either columns or rows (Figure 1(D)).

Stimulus organisation

Across trials, stimuli varied in level of organisation, which corresponds to the percentage of common elements along the vertical or horizontal orientation. Highly organised stimuli provide a robust cue for grouping, whereas grouping becomes increasingly ambiguous at lower levels of organisation. Stimulus organisation was manipulated by randomly alternating a percentage of elements. Examples of stimuli across a range of organisations are depicted in Figure 2.

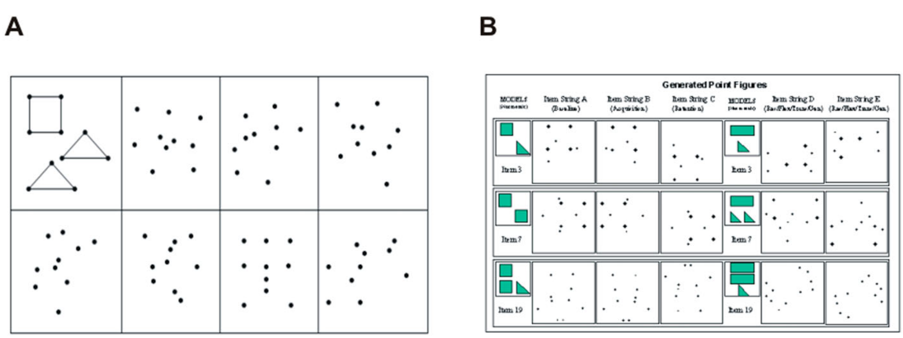

Figure 2. Examples of test items from the Feuerstein Instrumental Enrichment cognitive training system for training modules of (A) Organization of Dots and (B) Analytic Perception (reproduced by permission).

Procedure

Patients viewed stimuli from a distance of 46 cm. At the start of each trial, patients fixated on a yellow square that was centred on a computer monitor. Following a delay of 417 ms (25 cycles at 60 Hz refresh rate), a stimulus appeared for 417 ms. On each trial, the vertical or horizontal condition was randomly assigned. Following stimulus presentation, subjects indicated whether the stimulus was organised as a series of vertical or horizontal lines. Responses were made either verbally or by pointing to picture representations of the choices. Responses were then entered into the computer by the experimenter. For each stimulus feature, patients first received a demonstration, and then a series of practice trials in order to become familiar with the stimuli and procedure. Stimulus generation, data collection, and contingency algorithms were controlled by a computer (Bukhari & Kurylo, 2008).

For each trial block, trials began with highly organised stimuli (easier condition), and change in difficulty was contingent upon patients' performance. Specifically, performance was assessed for each block of 10 trials. The accuracy of 90% or 100% correct resulted in increased difficulty of 1%, whereas the performance of 70% or less resulted in decreased difficulty of 1%. No change in difficulty occurred for 80% correct responding. Across days, beginning difficulty was set to 3% easier than the final level of the previous session. These rules for assigning difficulty level to ensure that difficulty at the start of a session was within patients' ability, and that difficulty advanced systematically based upon patient performance.

Intervention 2: IE therapy

Patients assigned to the IE Therapy group ($n = 9$) participated in supervised therapy sessions using two modules from the Feuerstein IE cognitive training system. Under the supervision of therapists who are trained in the administration of these therapeutic modules, participants were provided with problem-solving strategies and feedback regarding the accuracy of their performance. Specifically, therapists helped patients analyse, synthesize, evaluate, and identify increasingly complex visual stimuli, as they were encouraged to develop meta-skills of attention, accuracy, and persistence.

IE therapy consisted of three therapy sessions of 45 minutes per week, for a total of 36 sessions. Therapists worked sequentially through perceptual organisation problems that systematically increased in difficulty. Training was administered individually to patients by a therapist, and progression through each of the modules depending on performance by each patient. Variability in patient ability was thereby accommodated by employing one-on-one therapy sessions.

The modules are designed hierarchically, and patients participate in a progressive treatment plan designed to move the learner from one level of the programme to the next. Two of the modules within the programme contain distinct activities designed to enhance visual attention whereas facilitating perceptual organisation: (1) Organisation of Dots and (2) Analytic Perception. The goal of both modules is to encourage attention to detail whereas facilitating perceptual organisational strategies.

Organization of Dots task. In the Organization of Dots task, participants were presented with sets of geometric shapes (i.e. triangles, squares, rectangles, and/or diamonds) and on the same page they were presented with a series of dots that corresponded to each of the angles contained within the shapes. Participants were encouraged to reconstruct the shapes by correctly and accurately connecting the dots. The therapist continuously guided participants (mediated learning) through the task as they employed measurement tools and strategies, such as measuring distances and angles among dots, to identify shapes all the whereas receiving corrective feedback from the therapist. This module was modified from the original IE programme to improve sustained attention, reduce distraction and enhance task compliance. In the original training tool, up to twenty tasks were represented on a single page, which often caused problems with selective attention and distractibility. In the modified version, performance requirements were preserved and all stimuli maintained the visual structure, integrity and spatial orientation presented in the original modules. However, each task was enlarged and presented on a separate page with the intent to enhance attention as patients focus on the organisational element of the task.

Analytic Perception task. For the Analytic Perception task, patients were required to either visually integrate component elements into "whole" geometric designs or deconstruct complex designs into their component constituents. By employing mediated learning, the therapist worked one-on-one with a participant to facilitate perceptual and learning strategies as subjects were encouraged to perform increasingly demanding perceptual organisation tasks.

Control Subjects

Patients assigned to the control condition ($n = 8$) completed a 12-week cognitive rehabilitation programme consisting of computer generated cognitive rehabilitation activities (CogPack). Activities in the control group condition consisted of attentionally demanding cognitive tasks that involve visual stimuli, however, these tasks were not designed to improve perceptual organisation. Patients participated in a variety of activities, including (1) attention/visual memory tasks, such as comparing visual images or shapes, connecting letters or numbers with a single line, or answering questions about the details of a visual scene; (2) motor tasks, such as stopping a watch at a specific time, or coordinating a movement with a moving object on a computer monitor; and planning/problem-solving tasks, such as solving an anagram or finding an exit in a drawing of a labyrinth. Patients in the control group received the same duration (45 minutes) and frequency (3 per week) of computer-based sessions and the same overall number of sessions.

Assessment of perceptual organisation

Perceptual organisation ability was assessed before and after the intervention. An additional measurement was made at the mid-point of training in order to track the course of improvement. The procedure use for perceptual organisation assessment was similar to that used for computer-based training, using the same stimulus set and discrimination task. For assessment, the perceptual ability was indexed in terms of perceptual grouping thresholds. Grouping thresholds represent the lowest level of stimulus organisation at which perceptual grouping could occur. Observers with reduced perceptually organisation ability require greater stimulus organisation in order to perceive visual patterns. Thresholds were measured by means of the psychophysical method of limits. A trial series began with 100% organisation and was then reduced by 2% after each consecutive pair of correct responses. The descending series continued until an error was made. Following an error, the difficulty level was reduced by 10%, and the descending series was repeated. Thresholds were based on the mean of eight descending series.

To minimize confounding factors associated with the slowed decision-making or motor response, reaction time was not a factor, and patients were instructed to optimize accuracy. In addition, responses were based upon a two-alternative forced-choice (2AFC) procedure, in which subjects indicated on each trial whether patterns were oriented vertically or horizontally. Psychophysical procedures employing 2AFC to determine threshold ensures subjects use unbiased decision criteria in order to preclude possible response bias.

Neuropsychological battery

Participants also received 13 neuropsychological tests that measured visual perception and cognitive functions (Table 2). The battery contained tests of visual perception, including visual organisation/visuospatial function (Contour Integration Test, where participants identify shapes defined by the orientation of Gabor elements (Silverstein et al., 2012); Picture Completion (WAIS-IV) (Wechsler, 1981); Hooper Visual Organization (Hooper, 1958)) and visual discrimination (Attention module of the Neuropsychological Assessment Battery (White & Stern, 2003); memory, including visuospatial memory (Brief Visual-Spatial Memory (MATRICS Consensus Cognitive Battery (Nuechterlein et al., 2008)); Spatial Span (MCCB (Nuechterlein et al., 2008))) and working memory (Letter-Number Span (MCCB (Nuechterlein et al., 2008))); attention (Dots Test (Spatial module of NAB (White & Stern, 2003)) ; Trail Making Test A (MCCB (Nuechterlein et al., 2008))); spatial reasoning/problem solving (Matrix Reasoning (WAIS-IV) (Wechsler, 1981)); and executive/initiation/divergent thinking (Category Fluency (MCCB (Nuechterlein et al., 2008)); Ruff Figural Fluency (Ruff, Light, & Evans, 1987)).

Results

Treatment groups benefited from each form of intervention, as demonstrated by improvement in perceptual organisation capacities as well as on select neuropsychological tests. Comparisons were made among subject groups by means of analysis of variance (ANOVA), followed by *post hoc* tests comparing each treatment group to control subjects

Table 2. Neuropsychological tests ranked in decreasing order of proximity to perceptual organisation.

Function	Test
Visual Organisation	Contour Integration Test
Visual Organisation, Visual Detail	Picture Completion
Visual Perception	Visual Discrimination
Visuospatial Perception	Hooper Visual Organization
Visuospatial Memory	Brief Visual-Spatial Memory
Visuospatial Working Memory	Spatial Span (WAIS)
Working Memory	Letter Number Sequencing
Attention	Dots Test
Visual Attention, Task Switch	Trail Making Test A
Spatial Reasoning, Problem Solving	Matrix Reasoning (WAIS)
Executive, Initiation, Divergent Thinking	Category Fluency
Executive, Initiation, Divergent Thinking	Ruff Figural Fluency Test
Reading and Language Comprehension	Wide Range Achievement Test: Reading

(HSD). Individual measurements that fell beyond 3 standard deviations from the mean performance of the group were considered outliers and not included in statistical analysis. Details of analyses are described separately for measures of perceptual organisation and neuropsychological tests.

Perceptual organisation

Separate analyses were performed for each stimulus feature. Pre-treatment measures differed significantly across groups for the colour condition ($F(2, 25) = 3.51$, $p < .05$), where *post hoc* test indicated that the IE group performed significantly higher than the computer training group (HSD, $p < .05$). Initial performance for the luminance, orientation and motion conditions did not differ across groups.

Examining perceptual thresholds before, at the mid-point, and after intervention (Figure 3(A)), control subjects did not change significantly across assessment periods for any of the stimulus features, indicating a lack of practice effects on the primary perceptual organisation outcome measure. In contrast, performance for treatment groups improved across assessments. Specifically, the pattern of improvement for the computer training group paralleled that of the IE therapy group for the luminance, colour, and motion condition. For both intervention groups, greatest improvement occurred in the initial period of training for the luminance condition. A similar pattern occurred for the computer training group with the orientation condition. In all other cases, performance improved progressively across the intervention period.

Comparing pre- and post-intervention assessment (Figure 3(B)), subject groups differed significantly on the luminance ($F(2, 25) = 11.64$, $p < .01$), colour ($F(2, 25) = 12.10$, $p < .01$) and orientation ($F(2, 26) = 4.71$, $p < .05$) conditions, whereas the groups did not differ significantly on the motion condition. *Post hoc* analyses of significant effects indicated that significantly greater improvement occurred for both intervention

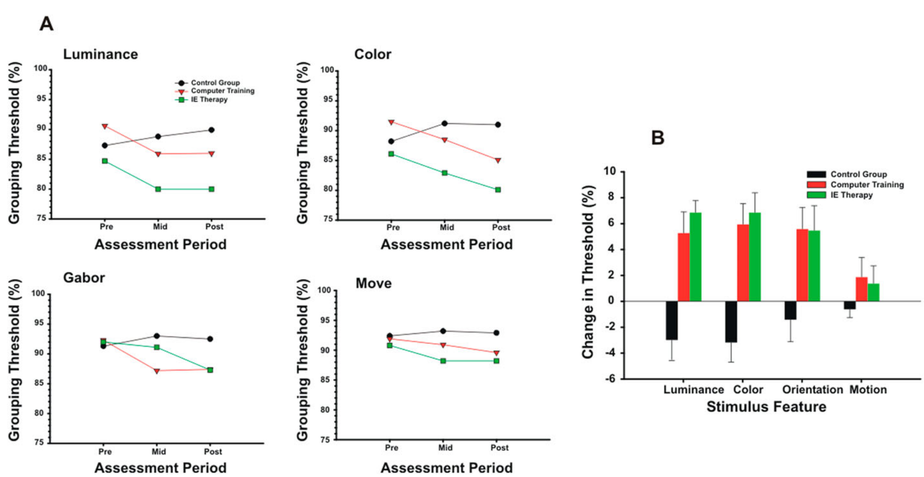

Figure 3. (A) Mean perceptual grouping thresholds for each subject group measured before, at the mid-point, and following intervention. (B) Change in the perceptual threshold between pre- and post-assessment for each subject group.

groups compared to control subjects ($p < .05$). For control subjects, a trend existed for reduced performance on the Luminance and Color conditions, although the change in performance did not differ significantly from zero ($t = -1.94$ and -2.13, for Luminance and Color conditions, respectively, $p > .05$). This non-significant trend may therefore simply reflect variability in test performance. Results indicate the effectiveness of both rehabilitation procedures, with different patterns of treatment-related change across perceptual organisation strategies (e.g. grouping by luminance vs motion cues, etc.).

Neuropsychological assessment

Performance on pre- and post-intervention neuropsychological tests varied widely among patients. Changes in performance across the intervention period for each subject group are displayed in Figure 4, organised from tests of perceptual organisation (far left), visuospatial perception, visuospatial memory, memory, attention, spatial reasoning, and divergent thinking/executive function (far right). For the control group, change in performance between pre- and post-assessment did not differ significantly from zero on any neuropsychological test (T-test, $p > .05$). For treatment groups, an overall trend of improved performance existed across tests, reaching statistical significance on select conditions. Specifically, significant differences across subject groups occurred for Contour Integration

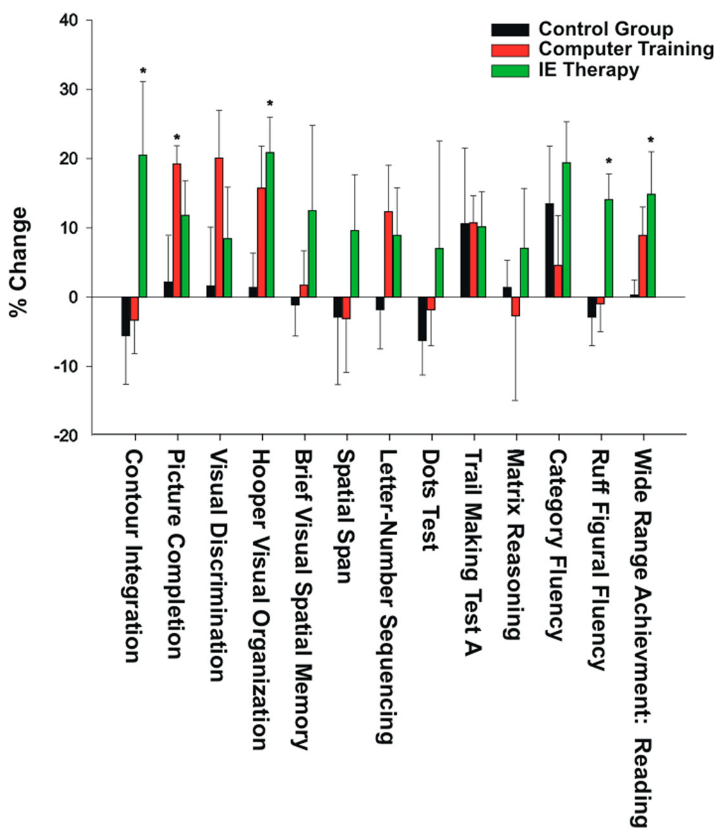

Figure 4. Change in performance between pre- and post-intervention for each neuropsychological test.

($F(2, 25) = 4.76$, $p < 0.05$), Picture Completion ($F(2, 25) = 3.85$, $p < 0.05$), Hooper Visual Organization ($F(2, 25) = 3.87$, $p < 0.05$), Ruff Figural Fluency ($F(2, 25) = 5.46$, $p < 0.05$), and Wide Range Achievement: Reading ($F(2, 25) = 3.60$, $p < 0.05$). In order to determine the source of the significant effects, *post hoc* tests were used to compare each treatment group to the control group. For computer training, a significant improvement occurred for the visuospatial test of Picture Completion ($p < .05$), whereas a non-significant trend towards improvement occurred for Visual Discrimination and Hooper Visual Organization. In addition, for computer training, a non-significant trend existed for improvement on Letter-Number Sequencing. For IE therapy, significant improvement occurred for the visuospatial tests of Contour Integration ($p < .05$) and Hooper Visual Organization ($p < .05$), and non-significant trends existed for improvement on Visual Discrimination, as well as on Spatial Span and Letter-Number Sequencing. For tests of attention/spatial reasoning/executive function, IE therapy produced significant improvement on Ruff Figural Fluency ($p < .05$) and Wide Range Achievement: Reading ($p < .05$).

Discussion

An evaluation was made of two rehabilitation protocols that target visual perceptual organisation. Computer-based training emphasised processing of perceptually grouped patterns, whereas IE therapy targeted cognitive strategies relevant to task demands. It was found that both forms of intervention improved perceptual organisation in patients with schizophrenia relative to a control intervention condition. In addition, interventions targeting perceptual organisation generalised to certain visual cognitive abilities. Of note, IE therapy more effectively improved test performance overall regardless of task content, a finding that might be expected given the top-down nature of the IE intervention.

Interventions improved perceptual organisation for the luminance, colour, and orientation conditions, whereas performance did not change significantly with motion stimuli. In each condition, stimuli were parallel in their global construction (two element sub-types that varied in level of organisation) but differed in stimulus feature. Differences found across conditions may, therefore, reflect differences in processing associated with each feature. Specifically, luminance and colour share stimulus properties associated with intensity and colour contrast (Conway, 2001; Peng and Van Essen, 2004), whereas line orientation (Yousef et al., 1999) and motion direction (Orban, Kennedy, and Bullier, 1986) are encoded with sets of properties specific to stimulus metrics. In addition, neural mechanisms associated with grouping by similarity (Han et al., 2005), which occur in the luminance and colour conditions, are distinguished from mechanisms proposed for contour integration (Altmann et al., 2003) and motion coherence (Handel et al., 2007). Differences in encoding and grouping may, therefore, account for different effects of intervention across stimulus conditions.

In addition to improving perceptual organisation, interventions benefitted certain visual cognitive functions, including visuospatial ability, nonverbal fluency, and reading. The pattern of improvement across neuropsychological tests did not map onto their degree of proximity to perceptual organisation. Results suggest more widespread effects of the intervention on high-order visual and cognitive processes that extend beyond stimuli used in training. Alternatively, an improvement on selective neuropsychological tests may reflect an improvement on factors such as sustained attention and working memory, which are regularly engaged with training procedures. Expanded analysis of stimulus structure in the context of neuropsychological tests will enable a better understanding of the association between perceptual organisation and more high-order functions.

Computer training was based upon repeated engagement of a discrimination task that requires perceptual organisation. Patients completed a sequence of successful trials before advancing to the next level of difficulty, gaining experience with successful processing of stimulus components. The regulated rate of increased difficulty thereby allowed exposure to multiple trials within participants' ability, which reinforce processes associated with perceptual organisation. In addition, feedback was provided, which allowed participants to monitor their performance and adapt processing to task conditions. Feedback serves as an effective method to enhance the speed of learning and performance accuracy (Herzog & Fahle, 1997), particularly for high difficulty levels (Seitz et al., 2006) or with low performance accuracy (Liu, Lu, & Dosher, 2010). Providing feedback as part of the training protocol thereby improves the effectiveness of training as stimulus difficulty advanced to higher levels.

A similar training protocol as that used here has been applied to healthy control subject in order to evaluate whether repeated engagement of perceptual organisation processes would enhance grouping ability (Kurylo, Waxman, Silverstein, & Kidron, 2017). Similar to patients with schizophrenia, healthy control subjects improved significantly on grouping based upon luminance, colour and orientation. However, unlike the patient group, healthy control subjects also improved significantly on grouping by motion, demonstrating increased thresholds at levels similar to the other stimulus features. The pattern of results found with healthy control subjects suggests that computer-based training produces adaptive changes to early levels of stimulus processing. Differences in training effects between the healthy control and schizophrenia group may reflect differences in cognitive or motivational factors, or in neurophysiological factors associated with adaptive changes in visual processing.

IE therapy employed therapist-guided learning, which promoted strategies to better identify, analyse, and synthesize stimulus characteristics relevant to task demands. Improving attention and problem-solving skills thereby improved effectiveness of stimulus processes. IE programme modules used here target relationships among stimulus components, thereby focusing therapy on perceptual organisation. As with computer training, the level of difficulty for IE tasks increased progressively, enabling successful performance before advancing to the next level of difficulty.

Results indicate that IE therapy improves lower and mid-level visual processes that operate within a brief timescale. IE therapy thereby enabled participants to quickly and effectively extract visual information, such as regularities in stimulus structure, that are relevant to task demands. In addition, stimuli used with IE therapy were dissimilar to those used for perceptual assessment, and therefore participants did not gain experience with stimuli used for assessment. Improved perceptual organisation with IE therapy, therefore, reflects adaptive changes that generalize to broader functions. Such effects may be reflected by the relatively greater benefit of IE therapy with neuropsychological tests, where improved perceptual and cognitive strategies had a more widespread impact across test conditions.

Patients differed in reception to each two therapeutic approaches, which may influence factors such as motivation and level of engagement. Computer training was generally received as part of patients' daily activities, and participants did not demonstrate signs of particular enjoyment or discomfort. For computer training, patients could monitor their level of achievement, and one patient commented that they enjoyed the challenge of improving scores across sessions. The majority of participants appeared to enjoy IE therapy, and some patients indicated that they found the activities to be a positive experience. Continued application of therapies may benefit from encouraging positive interactions with patients, and providing reinforcement through patient-therapist interactions as well as feedback on improvement in performance.

A limitation of the study is the relatively small number of subjects. Although significant effects with low subject numbers demonstrate the potential robustness of the intervention effects, they still need to be replicated with larger samples. The sample size used here are similar to those used in related studies (Butler, Thompson, Seitz, Deveau, & Silverstein, 2017; Contreras et al., 2018; Surti et al., 2011), reflecting the early stage of work in visual remediation in schizophrenia. Taken together, the data are consistent, and suggest that larger randomised controlled trials are needed now. Future research should include a broader sampling base, allowing sufficient sub-group numbers for comparisons of clinical sub-types, levels and categories of medication, and other demographic characteristics. In addition, further analysis may be made of individual differences in initial perceptual capacities, and details of individualised therapies and stimulus exposure, which may assist in protocol design in order to improve the effectiveness of interventions.

Protocols described here represent new rehabilitation methods in schizophrenia that target lower and mid-level visual processing. Additional research is required to examine the combined application of both forms of intervention, where an interaction may accelerate gains. Specifically, IE therapy, which serves to guide attentional resources and performance strategies, may enhance effects of computer-based training. It is notable that long-term hospital patients were able to complete the training and demonstrate effects, which suggests that the stimuli and format of this intervention are acceptable to patients and that even larger gains might be observed in patients with more intact perceptual and cognitive functions. Results contribute to the broader goals of developing adaptable programmes of intervention for patients with schizophrenia that serve to reduce symptoms and improve cognitive functions. Additional research is required to determine the longevity of effects, as well as the relationship of improved perceptual organisation to that of psychiatric symptoms and functional outcomes in the domains of socialisation, work, and academic function.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Adcock, R. A., Dale, C., Fisher, M., Aldebot, G. A., Simpson, G. V., Nagarajan, S., & Vinogradov, S. (2009). When top-down meets bottom-up: Auditory training enhances verbal memory in schizophrenia. *Schizophrenia Bulletin*, 35, 1132–1141.

Altmann, C. F., Bulthoff, H. H., & Kourtzi, Z. (2003). Perceptual organization of local elements into global shapes in the human visual cortex. *Current Biology*, *13*, 342–349.

Bukhari, F., & Kurylo, D. D. (2008). Computer programming for generating visual stimuli. *Behavior Research Methods*, *40*, 38–45.

Butler, P. D., Thompson, J. L., Seitz, A. R., Deveau, J., & Silverstein, S. M. (2017). Visual perceptual remediation for individuals with schizophrenia: Rationale, method, and three case studies.. *Psychiatric Rehabilitation Journal*, *40*, 43–52.

Chen, Y., Bidwell, L. C., & Holzman, P. S. (2005). Visual motion integration in schizophrenia patients, their first-degree relatives, and patients with bipolar disorder. *Schizophrenia Research*, *74*, 271–281.

Cocchi, L., Schenk, F., Volken, H., Bovet, P., Parnas, J., & Vianin, P. (2007). Visuo-spatial processing in a dynamic and a static working memory paradigm in schizophrenia. *Psychiatry Research*, *152*, 129–142.

Contreras, N. A., Tan, E. J., Lee, S. J., Castle, D. J., & Rossell, S. L. (2018). Using visual processing training to enhance standard cognitive remediation outcomes in schizophrenia: A pilot study. *Psychiatry Research*, *262*, 494–499.

Conway, B. R. (2001). Spatial structure of cone inputs to color cells in altert macaque primary visual cortex (V-1). *Journal of Neuroscience*, *21*, 2768–2783.

Corjoukov, I., Jeurissen, D., Kloosterman, N. A., Verhoeven, J. E., Scholte, H. S., & Roelfsema, P. R. (2012). *The time course of perceptual grouping in natural scenes*. *Psychological Science*, 23, 1482–1489.

Curby, K. M., Goldstein, R. R., & Blacker, K. (2013). Disrupting perceptual grouping of face parts impairs holistic face processing. *Attention Perception, and Psychophysics*, *75*, 83–91.

Feuerstein, R., Falik, L., & Feuerstein, S. (2010). *Beyond smarter: Mediated learning and the brain's capacity for change*. New York: Teachers College Press.

Feuerstein, R., & Feuerstein, S. (1991). Mediated learning experience: A theoretical review. In R. Feuerstein, P. Klein, & A. Tannenbaum (Eds.), *Mediated learning experience: Theoretical, psychosocial, and learning implications* (pp. 3–51). Tel Aviv: Freund.

Feuerstein, R., Rand, Y., Hoffman, M., Egozi, M., & Ben-Schachar, N., 1991. Intervention programs for retarded performers: Goals, means, and expected outcomes. In L. Idol and B. Jones (Eds.), *Educational values and cognitive instruction*. Vol. 2. Hillsdale, NJ: Erlbaum. Reprinted in M. Ben-Hur (Ed.), On Feuerstein's Instrumental Enrichment. Palatine, IL: IRI/Skylight, 1994.

Feuerstein, R., Rand, Y., Hoffman, M., & Miller, R. (1980). *Instrumental enrichment: An intervention program for cognitive modifiability*. Baltimore, MD: University Park Press.

Fisher, M., Holland, C., Subramaniam, K., & Vinogradov, S. (2010). Neuroplasticity-based cognitive training in schizophrenia: An interim report on the effects 6 months later. *Schizophrenia Bulletin*, *36*, 869–879.

Fisher, M., Loewy, R., Carter, C., Lee, A., Ragland, J. D., Niendam, T., … Vinogradov, S. (2015). Neuroplasticity-based auditory training via laptop computer improves cognition in young individuals with recent onset schizophrenia. *Schizophrenia Bulletin*, *41*, 250–258.

Han, S., Jiang, Y., Mao, L., Humphreys, G. W., & Gu, H. (2005). Attentional modulation of perceptual grouping in human visual cortex: Functional MRI studies. *Human Brain Mapping*, *25*, 424–432.

Handel, B., Lutzenberger, W., Thier, P., & Haarmeier, T. (2007). Opposite dependencies on visual motion coherence in human area MT+ and early visual cortex. *Cerebral Cortex*, *17*, 1542–1549.

Herzog, M. H., & Fahle, M. (1997). The role of feedback in learning a Vernier discrimination task. *Vision Research*, *37*, 2133–2141.

Hooper, H. E. (1958). *The Hooper Visual Organization Test manual*. Los Angeles, CA: Western Psychological Services.

Joshua, N., & Rossell, S. (2009). Configural face processing in schizophrenia. *Schizophrenia Research*, *112*, 99–103.

Kay, S. R., Opler, L. A., & Fiszbein, A. (1987). The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophrenia Bulletin*, *13*, 261–276.

Kurylo, D. D., Pasternak, R., Silipo, G., Javitts, D. C., & Butler, P. D. (2007). Perceptual organization by proximity and similarity in schizophrenia. *Schizophrenia Research*, *95*, 205–214.
Kurylo, D. D., Waxman, R., Silverstein, S. M., & Kidron, R. (2017). Visual training improves perceptual grouping based on basic stimulus features. *Attention*, *Perception, and Psychophysics*. *79*, 2098-2107. doi:10.3758/s13414-017-1368-8
Liu, J., Lu, Z.-L., & Dosher, B. A. (2010). Augmented Hebbian reweighting: Interactions between feedback and training accuracy in perceptual learning. *Journal of Vision*, *10*, 1–14.
Nuechterlein, K. H., Green, M. F., Kern, R. S., Baade, L. E., Barch, D. M., Cohen, J. D., et al. (2008). The MATRICS consensus cognitive battery, part 1: Test selection, reliability, and validity. *American Journal of Psychiatry*, *165*, 203–213.
Orban, G. A., Kennedy, H., & Bullier, J. (1986). Velocity sensitiviy and direction selectivity of neurons in areas V1 and V2 of the monkey: Influence of eccentricity. *Journal of Neurophysiology*, *56*, 462–480.
Peng, X., & Van Essen, D. C. (2004). Peaked encoding of relative luminance in macaque areas V1 and V2. *Journal of Neurophysiology*, *93*, 1620–1632.
Rabinowicz, E. F., Opler, L. A., Owen, D. R., & Knight, R. A. (1996). Dot enumeration perceptual organization task (DEPOT): Evidence for a short-term visual memory deficit in schizophrenia. *Journal of Abnormal Psychology*, *105*, 336–348.
Roelfsema, P. R., & Houtkamp, R. (2011). Incremental grouping of image elements in vision. *Attention, Perception, & Psychophysics*, *73*, 2542–2572.
Ruff, R. M., Light, R. H., & Evans, R. W. (1987). The Ruff figural fluency test: A normative study with adults. *Developmental Neuropsychology*, *3*, 37–51.
Sasaki, Y. (2007). Processing local signals into global patterns. *Current Opinion in Neurobiology*, *17*, 132–139.
Seitz, A. R., Nanez, J. E., Holloway, S. R., & Watanabe, T. (2006). Perceptual learning of motion leads to faster flicker perception. *PLoS ONE*, *1*(e28).
Seymour, K., Karnath, H. O., & Himmelbach, M. (2008). Perceptual grouping in the human brain: Common processing of different cues. *Neuroreport*, *19*, 1769–1772.
Silverstein, S. M., All, S. D., Kasi, R., Berten, S., Essex, B., Lathrop, K., & Little, D. M. (2010). Increased fusiform area activation in schizophrenia during processing of spatial frequency-degraded faces, as revealed by fMRI. *Psychological Medicine*, *40*, 1159–1169.
Silverstein, S. M., Bakshi, S., Chapman, R. M., & Nowlis, G. (1998). Perceptual Organisation of Configural and Visual Patterns in Schizophrenia: Effects of Repeated Exposure. *Cognitive Neuropsychiatry*, *3*, 209–223.
Silverstein, S. M., Bakshi, S., Nuernberger, S., Carpinello, K., & Wilkniss, S. (2005). Effects of stimulus structure and target-distracter similarity on the development of visual memory representations in schizophrenia. *Cognitive Neuropsychiatry*, *10*, 215–229.
Silverstein, S. M., Hatashita-Wong, M. H., Schenkel, L. S., Kovács, I., Feher, A., Smith, T. E., … Uhlhaas, P. (2006). Reduced top-down influences in contour detection in schizophrenia. *Cognitive Neuropsychiatry*, *11*, 112–132.
Silverstein, S. M., & Keane, B. P. (2011). Perceptual organization impairment in schizophrenia and associated brain mechanisms: Review of research from 2005 to 2010. *Schizophrenia Bulletin*, *37*, 690–699.
Silverstein, S. M., Keane, B. P., Barch, D. M., Carter, C. S., Gold, J. M., Kovács, I., MacDonald, A. 3rd, Ragland, J. D., & Strauss, M. E. (2012). Optimization and validation of a visual integration test for schizophrenia research. *Schizophrenia Bulletin*. 38, 125–134.
Silverstein, S. M., Keane, B. P., Papathomas, T. V., et al. (2014). Processing of spatial-frequency altered faces in schizophrenia: Effects of illness phase and duration. *PLoS ONE*, *9*, e114642.
Surti, T. S., Corbera, S., Bell, M. D., & Wexler, B. E. (2011). Successful computer-based visual training specifically predicts visual memory enhancement over verbal memory improvement in schizophrenia. *Schizophrenia Research*, 132 (2–3), 131–134.
Surti, T. S., & Wexler, B. E. (2012). A pilot and feasibility study of computer-based training for visual processing deficits in schizophrenia. *Schizophrenia Research*, *142*, 248–249.

Turetsky, B. I., Kohler, C. G., Indersmitten, T., Bhati, M. T., Charbonnier, D., & Gur, R. C. (2007). Facial emotion recognition in schizophrenia: When and why does it go awry? *Schizophrenia Research*, *94*, 253–263.

Uhlhaas, P. J., & Silverstein, S. M. (2005). Perceptual organization in schizophrenia spectrum disorders: A review of empirical research and associated theories. *Psychological Bulletin*, *131*, 618–632.

Van Essen, D. C., Anderson, C. H., & Felleman, D. J. (1992). Information processing in the primate visual system: An integrated systems perspective. *Science*, 255, 419-423.

Wechsler, D. (1981). Manual for the Wechsler adult intelligence scale – revised. San Antonio, TX: The Psychological Corporation.

White, T., & Stern, R. A. (2003). *NAB, neuropsychological assessment battery: Psychometric and technical manual*. Lutz, FL: Psychological Assessment Resources.

Yousef, T., Bonhoeffer, T., Kim, D.-S., Eysel, U. T., Toth, E., & Kisvarday, Z. (1999). Orientation topography of layer 4 lateral networks revealed by optical imaging in cat visual cortex (area 18). *European Journal of Neuroscience*, *11*, 4291–4308.