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Global Processing Takes Time: A Meta-Analysis on Local–Global Visual Processing in ASD

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What does an individual with autism spectrum disorder (ASD) perceive first: the forest or the trees? In spite of 30 years of research and influential theories like the weak central coherence (WCC) theory and the enhanced perceptual functioning (EPF) account, the interplay of local and global visual processing in ASD remains only partly understood. Research findings vary in indicating a local processing bias or a global processing deficit, and often contradict each other. We have applied a formal meta-analytic approach and combined 56 articles that tested about 1,000 ASD participants and used a wide range of stimuli and tasks to investigate local and global visual processing in ASD. Overall, results show no enhanced local visual processing nor a deficit in global visual processing. Detailed analysis reveals a difference in the temporal pattern of the local–global balance, that is, slow global processing in individuals with ASD. Whereas task-dependent interaction effects are obtained, gender, age, and IQ of either participant groups seem to have no direct influence on performance. Based on the overview of the literature, suggestions are made for future research.

Keywords: autism spectrum disorder, developmental disorders, meta-analysis, perception, vision science

Autism Spectrum Disorder

The first mentioning of autism spectrum-like pathology stems from the early 1940s. Leo Kanner (1943) used the term "*early infantile autism*" to refer to children who he found suffering from "extreme aloneness from the very beginning of life," impaired social responsiveness and an obsessive desire for the "preservation of sameness." Independently from Kanner, Hans Asperger (1944, translated by Frith, 1991) used the term "*autistic psychopathology*" to refer to four children who were showing social withdrawal and obsessive interests. Both Kanner's and Asperger's first observations and descriptions already captured the essence of autism spectrum disorder as we still know it today, although many modifications to the concept have been made over the years.

Nowadays, "autism spectrum disorder" (ASD) represents a broad set of early onset neurodevelopmental psychiatric disorders, that are characterized by persistent deficits in social communication and social interaction, as well as restricted, repetitive patterns of behavior, interests, or activities (*DSM-5*, American Psychiatric Association, 2013).[1] The core symptoms include atypicalities or deficits in (developmental) areas such as speech, language, relationship building, or sensory processing. Although the disorder is generally characterized by an early onset and chronic nature, the specific symptomatology and severity of the disorder may vary strongly among individuals.

Insight into the etiology of ASD is still limited. Although strong heritability rates (40%–88%) with a modest shared environment component (0%–32%) suggest that ASD is predominantly genetically determined (Ronald & Hoekstra, 2011), it remains unclear which specific genes or neurological pathways are involved. Investigating the etiology is not only complicated by interacting psychosocial and environmental factors, but also by the large heterogeneity at both the phenotypic and genetic level, with variations across and within domains of functioning, as well as variation in severity of symptoms (Rommelse, Geurts, Franke, Buitelaar, & Hartman, 2011). Only in 10% of all ASD cases, the pathology is due to known genetic syndromes such as fragile X syndrome, tuberous sclerosis, Cornelia de Lange syndrome, or neurofibromatosis (Persico & Napolioni, 2013). Despite the large heterogeneity, neuropsychological studies have attempted to identify crucial differences between typically developing (TD) individuals and individuals with ASD on executive functioning, theory of mind, or sensory processing (Viding & Blakemore, 2007). A vast majority of

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[1] With the recent developments of the *DSM-5* in mind (American Psychiatric Association, 2013), this article will not distinguish between "autism," "Asperger's disorder," "PDD-NOS" and other ASD diagnoses present in the *DSM–IV–TR* (American Psychiatric Association, 2000), but will consistently refer to "ASD" to avoid confusion or misunderstanding.

sensory processing-related research in ASD has been focusing on atypical perceptual organization.

Atypical Perceptual Organization

To be able to perceive meaningful patterns in arrays of ever-changing information, our minds have to combine separate bursts of information into more organized units of perception. By detecting *coherence* in the bits and pieces of (local) information, we are able to compose a global, meaningful *Gestalt* that will allow us to understand our surroundings. We gather information on *where* and *what* something is, to be able to make sense of and interact with the external world. This ability, referred to as "perceptual organization" (see Wagemans, Elder, et al., 2012 and Wagemans, Feldman, et al., 2012 for extensive reviews), is crucial in being able to *relate to* one's surroundings. The importance of perceptual organization is especially apparent in view of the detrimental effects of this process going awry: A deficit in perceptual organization will not merely hamper object and scene perception, but will also affect one's social abilities, as accurate visual perception underlies being able to *read* a face or *grasp* a social scene.

ASD research on perceptual organization is mostly focused on local–global visual processing, as the successful outcome of the organizational process is dependent on the balanced interplay of perceiving local and global order (Kimchi, 1992). How can one understand what "local" and "global" order entail in terms of visual processing? Perception of local order encompasses situations where processing is restricted to smaller regions of the visual field or is concerned with attributes of a visual stimulus that can be processed in isolation. To perceive specific details or local order in general, no interaction between different aspects of the visual field is needed. Perception of global order, however, involves processing that is dedicated to larger regions of the visual field. It allows us to make abstraction of the details and to focus more on the general aspects in order to grasp the full picture or the entire visual scene. Interaction between the different aspects of the visual field is required, as merely processing different attributes of the visual field in isolation will not result in an overall composition or a global gist.

Initial Studies in ASD

The first report of atypical perceptual organization in individuals with ASD is by Shah and Frith (1983) and constitutes a pivotal study. Children with ASD outperformed matched control samples on an Embedded Figures Test, where they were asked to detect target shapes that were embedded within larger shapes. Later on, a second study by Shah and Frith (1993) followed: Individuals with ASD, regardless of age and intellectual ability, outperformed control samples on unsegmented variations of the Block Design task. Frith and Happé (1994) argued that these two results reflected an abnormal ease to segment in individuals with ASD. The authors hypothesized that "the struggle to resist overall Gestalt forces" as found in typical development (Koffka, 1935), might not occur in autistic subjects. Shah and Frith's (1983, 1993) reports of atypical processing in ASD were the first of a wide variety of empirical findings to follow.

An Array of Paradigms

Whereas Shah and Frith used the Children's Embedded Figures test and the classical Block Design task to tap into local–global visual processing, many other tasks and paradigms have been developed since to examine how and to what extent the interplay of local and global perception in ASD differs from the interplay in typical development (for reviews and theories, see Behrmann, Thomas, & Humphreys, 2006; Happé & Booth, 2008; Mottron et al., 2013). A first, popular paradigm that has been used to examine local–global visual processing is the Navon paradigm (Navon, 1977), where participants are presented with hierarchical letters or figures that hold information at both the local and the global level.[2] Examples are a letter H that is build up from several small letters L or a large triangle that is build up from several small squares. By means of reaction times (RTs) or reports on what participants *perceive first* when presented with the two-level stimulus [(in)consistent local and global information], researchers have tried to determine whether individuals with ASD are quicker at grasping the local level, slower at grasping the global level, or neither, compared with typically developing individuals. Researchers have also used visual illusions (e.g., Müller-Lyer, Ebbinghaus) to test how strongly the global Gestalt affects the ASD viewer. A diminished susceptibility to visual illusions is interpreted as an indication of a lower sensitivity to global information or a reduced interference from automatic processing of global order on perception of local attributes (e.g., length or size of an element). Furthermore, researchers have often administered visual search tasks with targets defined by single features (e.g., blue cross amongst red crosses) versus conjunctions (e.g., blue cross amongst blue circles and red crosses). The speed with which participants are able to find a feature target is taken as an indication of the ease with which one attends to local information, while the speed in a conjunction search is taken as an indication of how easily an individual can integrate information. Other than the above described paradigms, ASD researchers have used categorization tasks to examine the use of narrow versus broad categories (with details being preserved or filtered out), or drawing tasks to examine the temporal unfolding of extracted and reproduced visual representations (from local to global or vice versa).

Theoretical Frameworks

Since the first reports of atypical visual processing in ASD in the 1980s, two major neurocognitive frameworks have been developed and refined to try and understand perceptual organization in ASD.

A first framework is Frith's weak central coherence (WCC) theory, which was originally built on the observation of a local processing bias in the ASD population, as described earlier (Frith & Happé, 1994; Happé & Booth, 2008; Happé & Frith, 2006). The observation of ease with segmentation was later on combined with the observation of a relative failure to extract "the bigger picture" in individuals with ASD. Nowadays, the WCC theory postulates

[2] Note that when the "level" of the visual property is discussed, this corresponds to the place it occupies in the visual hierarchy: properties at the top of the visual hierarchy are more global than those at the bottom, which in turn are more local. The terminology does not include any claims with regard to where they are processed within the cortical hierarchy.

that individuals with ASD seem to have difficulties integrating information into a meaningful whole or incorporating the context, although their attention to and processing of local-level information seems enhanced or at least preserved. In addition, Happé and Booth (2008) have postulated the idea of independence of local and global processing, arguing that local and global processing seem to rely on different mechanisms and seem to follow different developmental trajectories.

A second, important framework is the enhanced perceptual functioning (EPF) hypothesis which, unlike the WCC theory, emphasizes enhanced local-level processing in people with ASD and does not claim a qualitative or quantitative deficiency in the ability to process global-level information (Mottron & Burack, 2001; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). The EPF theory suggests that global perception has a more optional character in ASD, whereas in the general population it is quite mandatory and automatic. This holds that an individual with ASD is likely still able to see the bigger picture, but only when he or she is specifically instructed to do so. There is no absolute failure of extracting the gist in individuals with ASD, but a lack of doing so automatically (Mottron et al., 2006). In addition, Mottron et al. (2013) have suggested a developmental predisposition for "elaborate veridical mapping across isomorphic perceptual and nonperceptual structures" as underlying mechanism for EPF and as a mechanism to explain the high incidence of savant abilities in ASD.

Although both theoretical frameworks have been investigated for years, evidence for either lines of theory is mixed and ambiguously interpretable. Thirty years of examining local–global perception in ASD has yield inconsistent and often contradictory results (for reviews, see Behrmann et al., 2006; Simmons et al., 2009). Although some researchers find visual atypicalities for ASD in terms of enhanced local perception and others in terms of a diminished performance for global order perception, many have failed to replicate these or other often reported phenomena. In line with the existing evidence, conceptual differences between WCC and EPF have decreased considerably since they first originated. Both frameworks now attribute a more locally oriented processing style to individuals with ASD (in contrast to a more globally oriented one in typical development), and postulate these specific differences as tendencies or inclinations, rather than as an all-or-nothing competence in Gestalt processing. However, taking into account the field's pitfalls and difficulties, it is hardly surprising that not all of the evidence pertaining to local–global visual processing has been properly explained and no one line of theory is able to integrate all research findings (Happé & Booth, 2008; Mottron et al., 2013; Simmons et al., 2009).

Mixed Evidence

A major problem with the existing research is that most studies differ in numerous ways, for instance, by employing different participant groups, different stimuli, or different task demands. The impact of such differences has been shown by several interesting studies. For example, Koldewyn, Jiang, Weigelt, and Kanwisher (2013) provided evidence of an effect of task demands on the perceptual process in ASD, and Scherf, Behrmann, Kimchi, and Luna (2009; Scherf, Luna, Kimchi, Minshew, & Behrmann, 2008) demonstrated the importance of age effects on perceptual organization. The heterogeneity present within the literature makes simple generalization across studies difficult and exceptionally problematic. An additional problem constitutes the variation in scholars' conceptualization and operationalization of "local" and "global" visual processing. Up until today, no clear guidelines exist on how to operationalize "local" or "global," and views are mixed on how they relate to each other (Happé & Booth, 2008). Only a few attempts have been undertaken to validate the constructs or to clarify their relationship (Happé & Booth, 2008; Milne & Szczerbinski, 2009). In general, operationalization of local and global properties (as defined in the local–global paradigm) seems to involves size: global properties are by definition larger than local properties (because the global configuration is necessarily larger than the local elements of which it is composed; Wagemans, Feldman, et al., 2012). Although this may sound simple, this rule-of-thumb does not translate into clear-cut research guidelines. For instance, one could argue about how to define "local" and "global" in a complex drawing such as the Rey-Osterrieth complex figure, as the size of an element depends on which substructures one compares with each other. An exploratory factor analysis by Milne and Szczerbinski (2009) of all results obtained with different paradigms concerning local–global perceptual processing has suggested that these paradigms do not measure a similar, unitary construct, and performance on these tasks can therefore be interpreted in several different ways. Unfortunately, such conceptual and operationalization problems set limits to how well one can interpret empirical results and rely on these paradigms to obtain consistent and interpretable findings.

Aim of the Present Study

Rather than yearning for new experimental research the existing literature is in need of an extensive, quantitative review of the available data, in which the overall effect size across different studies is assessed and the impact of potentially influential moderators and across-study differences are investigated. Therefore, this article will apply a meta-analytic approach to properly examine local–global visual perception in individuals with ASD compared with typically developing populations. We will focus on a wide range of tasks and paradigms (i.e., block design, categorization, discrimination, drawing, embedded figures, hierarchical figures, visual illusions, and visual search) and examine the influence of a wide range of potential moderators. By analyzing large collections of data from individual studies, we aim (a) to examine the nature of atypicalities in perceptual organization in ASD, (b) to investigate how "local" and "global" visual processing relate to each other, and (c) to get a better idea of possible moderators that rule the diversity.

Method

Literature Search

In order to find eligible studies, we conducted both a computerized and manual literature search. In the computerized literature search we explored titles, abstracts, and keywords in Web of Science using the following Boolean operation combining four main components: ("autis*" OR "asperger*" OR "pervasive developm*" OR "PDD-NOS" OR "PDD/NOS" OR "PDDNOS" OR "savant*" OR "AS*") AND ("experiment*" OR "control*" OR "condition" OR "group*") AND ("visu*" OR "vision" OR "seeing" OR "percept*" OR "illusion*" OR "embedded figure*" OR "configura*" OR "block*") AND ("local" OR "global" OR "detail*" OR "holistic" OR "enhanc*" OR "discriminat*" OR "search" OR "central coheren*" OR "context" OR "gestalt" OR "abilit*").

The computerized search covered a wide time span (January 1983–July 2013) and resulted in 1,415 hits. The broad set of key words resulted in a large amount of false hits, but at the same time warrants the inclusion of most relevant research material. The manual literature search encompassed a search of reference lists of review articles and primary study articles, and did not yield any additional research material that was missed in the computerized search.

Titles, abstracts and, when necessary, full texts of articles were screened with strict inclusion criteria. We included only studies from published journal articles in English, comparing a group of participants with ASD with a group of typically developing individuals. Master theses, doctoral theses, or conference presentations were not included. We limited the analysis to experimental studies that employed a behavioral task on local and/or global processing with static, nonface stimuli in the visual modality (as both motion perception as well as face perception are rather diverse and large areas of research in themselves). Neuroimaging or electroencephalographic studies were included only in case they employed a behavioral task and reported the corresponding data. In addition, summary data regarding the behavioral outcome measure(s), either in terms of accuracy, error rates, or RTs, had to be present in the article or provided in appendix material to be included in the analysis.

The selection and exclusion process of all abstracts yield in the literature search was done by four researchers, including the first, third, and last author. One hundred twenty-five of all 1,415 abstracts were judged independently by all four researchers. Agreement on inclusion or exclusion of articles between these four researchers was checked for these data, resulting in a Fleiss' Kappa of 96.5%. The remaining abstracts were divided amongst the four raters and judged by one of them. In case of uncertainty, the abstract was discussed amongst the four researchers. Of all the studies that were yielded by the automatic article search, about 90.0% was labeled as false positives. The most frequent reasons for exclusion were that the article (a) did not discuss local and/or global processing in the visual modality (but a different topic or a different modality); (b) did not administer the task to individuals with ASD (but used ASD-relatives or typically developed individuals with ASD traits; or (c) did not report the necessary behavioral outcome data (summary data solely present in graphs or figures). An overview of the in and exclusion process is shown in Figure 1. The inclusion and exclusion process resulted in a set of 56 individual articles on perceptual organization of static, nonface stimuli.

Coding

All studies were coded by the first or third author. Studies coded by the third author were double-checked by the first author. The selected 56 articles were coded for the following variables:

1. Age: Mean and standard deviation for both participant groups.
2. Full scale IQ (FSIQ): Mean and standard deviation for both participant groups.
3. Nonverbal IQ (NVIQ): Mean and standard deviation for both participant groups.
4. Gender ratio for both participant groups.
5. Type of task.
6. Type of visual processing, that is, local and/or global, necessary in the task.
7. Performance: Mean and standard deviation for both participant groups.

To code age, based on the mean age of the participant groups, three categories were constructed: a group of young children (6y < age ≤ 12y), an adolescent group (12y < age ≤ 18y) and a group of young adults (18y < age ≤ 35y). To code for intellectual

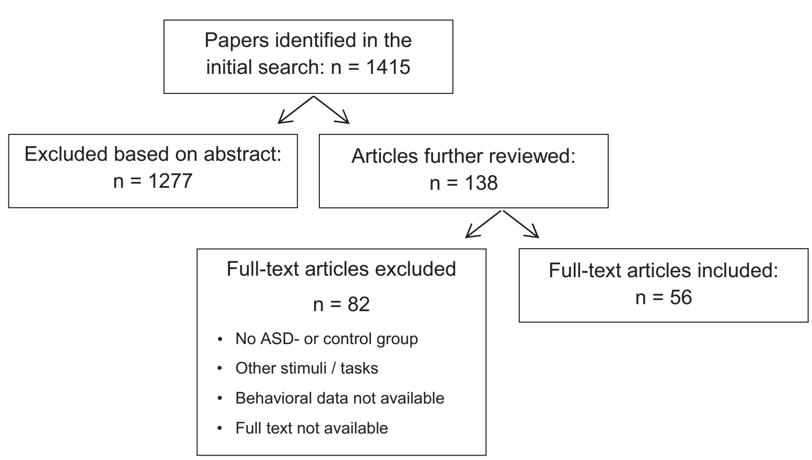

Figure 1. Selection process. This flowchart displays the entire in- and exclusion process of gathering articles to be included in the meta-analysis.

ability, FSIQ and NVIQ were coded and subdivided into three categories: a low intelligence ($40 < IQ \leq 70$), midlow intelligence ($70 < IQ \leq 100$) and average-high intelligence ($100 < IQ \leq 120$) group. Note that in case FSIQ was not provided, a best possible estimate of FSIQ was constructed based on the IQ information that was available. Although the authors aimed at creating more subgroups, that is, a younger age group and superior IQ group, the distribution of means and standard deviations of both participant groups did not allow for this. To code for the gender of the participant groups, a distinction was made between all male participant groups, all female participant groups and groups that contained both males and females.

To code the type of task that was applied, the different tasks were subdivided into eight categories, namely block design, categorization, discrimination, drawing, embedded figures, hierarchical figures, visual illusions, and visual search.

To code the type of visual processing used in a particular study, information about the presented stimuli was coded in two distinct ways; first, we coded the primary, task-relevant level of visual processing participants were instructed to attend to, and second, we coded the level(s) of visual information actually present in the stimuli, that is, the level(s) participants *could* attend to or could be distracted by (task-relevant as well as task-irrelevant). The latter coding is, evidently, nested in the first (see Table 1) but was added to the coding scheme in order to be able to examine the question of (in)dependence of local–global levels of processing and sensitivity to local–global interference. This way of coding the stimulus information was designed to grasp the level(s) of visual processing presented in the stimuli, rather than specific aspects with respect to task demands or overall task complexity. Secondary, task-irrelevant elements that were coded are, amongst others, the small letters in a Navon task where participants are asked to selectively attend the global letter, the (meaningful) larger figure in an embedded figures test where participants are asked to find the local target, or the global pattern in an unsegmented block design task.

To code task performance of each study present in the set of 56 articles, sample sizes and descriptive statistics on accuracy rates (including error rates or threshold values transformed into accuracy rates) and/or RTs were collected. If both information on accuracy and reaction time (RT) were present for one study, the two were coded as separate entries in the analysis. In case not all necessary descriptive statistics were available, information on test statistics (t, F, χ^2 or p values) was collected. To accommodate the issue of missing p values for null reports, the corresponding missing p values were assumed as $p = 1.00$. For articles reporting more than one experimental group or more than one typically developing control group, all intergroup comparisons were included in the analysis. Where performance measures had been recorded but not enough data was present in the article to allow for calculating an effect size (e.g., data plotted but not listed as numbers), the data were not included the analysis. The authors did not contact any of the corresponding authors with a request of providing any of the missing data. Detailed information on the 56 articles included in the analysis is presented in Table 2.

Data Analysis

For each observation, using the descriptive or test statistics present in the included articles, we calculated Hedges' g, as the estimate of the difference in population means divided by the common standard deviation, assuming a common variance under both conditions. A standard correction to Hedges' g was applied to account for a bias for small sample size (Hedges, 1981). In addition, we estimated the standard error σ_g of each observation, as it is used to determine the weight of each effect size, and to estimate the precision of the estimates of the parameters of our meta-analytic model. All calculations and conversions were done using Microsoft Office Excel. Hedges' g is a negative digit when the ASD group is outperformed by the typically developing group and a positive digit when the ASD group outperforms the typically developing group (see Table 2). According to the guidelines of Cohen (1988), an absolute effect size of 0.2 to 0.3 is regarded as a small effect, around 0.5 as a medium effect and from 0.8 on as a large effect.

All meta-analyses were conducted with Hedges' g as dependent variable. Each individual effect size was weighted by the estimated precision, the inverse of the (estimated) variance of the effect size estimate. Because the data of most studies resulted in more than one effect size, a traditional (two-level) random effects model was extended to a three-level random effects model (Van den Noortgate, López-López, Marín-Martínez, & Sánchez-Meca, 2013). Henceforth, variation is taken into account in terms of (a) random sampling variation of observed effect sizes, (b) variance between outcomes studied within the same study, and (c) between-study variance. This three-level model is a linear model that entails a residual term for each kind of variance. The simplest model, a model without moderator variables, is given in Equation 1:

$$g_{jk} = \beta_0 + v_{\cdot k} + u_{jk} + e_{jk} \tag{1}$$

Where g_{jk} is the observed effect size for outcome j within study k; β_0 is the overall mean effect size, across all outcomes and studies. Element $v_{.k}$ refers to the random deviation of the (mean) effect in study k from the overall effect over studies, u_{jk} to the deviation of the effect for outcome j in study k from the mean effect in study k, and e_{jk} is the residual due to sampling fluctuation, indicating the

Table 1
Coding the Level(s) of Visual Processing in a Task or Task-Condition

Secondary (task-irrelevant) level of processing	Primary (task-relevant) level of processing: Local	Primary (task-relevant) level of processing: Global
Absent or nonconflicting	Local–Local *e.g., Segmented Block Design*	Global–Global *e.g., Large letter of a congruent Navon letter*
Present and conflicting	Local–Global *e.g., Embedded Figures Test*	Global–Local *e.g., Rey-Osterrieth Complex Figure*

Table 2
Studies on Local–Global Visual Processing Included in the Meta-Analysis

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
1	Baldassi et al. (2009)	/	6–12y	70–100	70–100	12	/	12–18y	70–100	70–100	15	VS	Acc	L	−5,87	0,89	1,27
															−5,66	0,86	1,35
2a	Bölte, Duketis, Poustka, & Holtmann (2011)	F	12–18y	70–100	70–100	21	F	12–18y	100–120	100–120	35	BDT	Acc	L(G)	0,08	0,28	13,12
							M	12–18y	100–120	100–120	23				0,12	0,30	10,96
		M	12–18y	70–100	70–100	35	M	12–18y	100–120	100–120	23	BDT	Acc	L(G)	0,41	0,27	13,61
							F	12–18y	100–120	100–120	35				0,38	0,24	17,19
2b	Bölte, Duketis, Poustka, & Holtmann (2011)	F	12–18y	70–100	70–100	21	F	12–18y	100–120	100–120	35	EFT	RT	L(G)	−0,34	0,28	12,95
							M	12–18y	100–120	100–120	23				−0,73	0,31	10,30
		M	12–18y	70–100	70–100	35	M	12–18y	100–120	100–120	23	EFT	RT	L(G)	−0,63	0,27	13,24
							F	12–18y	100–120	100–120	35				−0,10	0,24	17,48
3a	Bölte, Holtmann, Poustka, Scheurich, & Schmidt (2007)	M	18–35y	100–120	100–120	15	M	18–35y	100–120	100–120	15	EFT	RT	L(G)	0,36	0,37	7,38
3b	Bölte, Holtmann, Poustka, Scheurich, & Schmidt (2007)	M	18–35y	100–120	100–120	15	M	18–35y	100–120	100–120	15	BDT	Acc	L(G)	0,24	0,37	7,45
3c	Bölte, Holtmann, Poustka, Scheurich, & Schmidt (2007)	M	18–35y	100–120	100–120	15	M	18–35y	100–120	100–120	15	VI	Acc	L(G)	1,25	0,40	6,28
3d	Bölte, Holtmann, Poustka, Scheurich, & Schmidt (2007)	M	18–35y	100–120	100–120	15	M	18–35y	100–120	100–120	15	HF	Acc	L(G)	0,51	0,37	7,26
4	Bölte, Hubl, Dierks, Holtmann, & Poustka (2008)	M	18–35y	100–120	100–120	7	M	18–35y	100–120	100–120	7	BDT	Acc	L(G)	−0,37	0,54	3,44
													RT	L(G)	−1,34	0,59	2,86
5	Booth, Charlton, Hughes, & Happé (2003)	M	6–12y	70–100	100–120	30	M	6–12y	100–120	100–120	31	DT	Acc	G	−0,91	0,27	13,81
6	Brosnan, Gwilliam, & Walker (2012)	M	12–18y	/	/	13	M	12–18y	/	/	13	EFT	Acc	L(G)	2,25	0,50	3,98
													RT	L(G)	2,08	0,49	4,22
7	Chen, Lemonnier, Lazartigues, & Planche (2008)	M	6–12y	70–100	70–100	14	M	6–12y	70–100	70–100	14	EFT	Acc	L(G)	−0,47	0,38	6,81
															0,32	0,38	6,91
8	Damarla et al. (2010)	M/F	18–35y	100–120	100–120	13	M	18–35y	100–120	100–120	13	EFT	Acc	L(G)	−1,60	0,45	4,93
													RT	L(G)	−0,09	0,39	6,49
9	de Jonge, Kemner, Naber, & Van Engeland (2009)	/	12–18y	100–120	100–120	23	/	12–18y	70–100	70–100	36	BDT	Acc	L(G)	0,59	0,27	13,48
10	de Jonge, Kemner, & Van Engeland (2006)	/	18–35y	70–100	70–100	18	/	18–35y	70–100	70–100	29	EFT	Acc	L(G)	0,50	0,30	10,79
															0,83	0,31	10,27
													RT	L(G)	0,62	0,31	10,62
11	Happé (1996)	/	12–18y	/	40–70	25	/	6–12y	/	70–100	26	VI	Acc	L(G)	−1,18	0,30	10,85
															−0,18	0,28	12,69
								6–12y	/	70–100	21	VI	Acc	L(G)	−1,81	0,35	8,12
															−0,25	0,30	11,32
12	Hayward et al. (2012)	M/F	18–35y	/	100–120	12	M/F	18–35y	/	100–120	12	HF	RT	G(L)	−0,05	0,41	6,00

Table 2 (*continued*)

Nr	Study	Participants with ASD: Sex	Age	NVIQ	FSIQ	*N*	Participants without ASD: Sex	Age	NVIQ	FSIQ	*N*	Task: Type	Measure	Level of visual processing	Results: *g*	*SE*(*g*)	*P*
															−0,12	0,41	5,99
															−0,07	0,41	6,00
														L (G)	0,06	0,41	6,00
															0,05	0,41	6,00
															0,06	0,41	6,00
13	Iarocci, Burack, Shore, Mottron, & Enns (2006)	M/F	6–12y	100–120	/	12	/	6–12y	100–120	/	12	VS	RT	L (G)	−3,51	0,65	2,36
															−0,60	0,42	5,74
														G (L)	−3,73	0,68	2,19
															−0,78	0,42	5,58
14	Ishida, Kamio, & Nakamizo (2009)	M	12–18y	70–100	70–100	9	M	6–12y	/	70–100	9	VI	Acc	L (G)	−1,45	0,53	3,56
															−0,98	0,50	4,02
															0,43	0,48	4,40
															0,60	0,48	4,30
15a	Jarrold, Gilchrist, & Bender (2005)	M	12–18y	40–70	40–70	18	/	6–12y	40–70	40–70	18	EFT	RT	L (G)	1,12	0,36	7,78
15b	Jarrold, Gilchrist, & Bender (2005)	M	12–18y	40–70	40–70	18	/	6–12y	40–70	40–70	18	VS	RT	L	1,40	0,37	7,23
															1,78	0,39	6,46
16	Jolliffe & Baron-Cohen (1997)	M/F	18–35y	100–120	100–120	17	M/F	18–35y	100–120	100–120	17	EFT	Acc	L (G)	0,41	0,35	8,33
															−0,82	0,36	7,83
															0,32	0,35	8,39
															−0,67	0,35	8,05
17	Jolliffe & Baron-Cohen (2001)	M/F	18–35y	100–120	100–120	17	M/F	18–35y	100–120	100–120	17	D	Acc	G (L)	−1,09	0,37	7,40
															−0,55	0,35	8,19
															−0,45	0,35	8,29
															0,17	0,34	8,47
													RT	G (L)	−1,82	0,41	6,01
															−1,62	0,40	6,40
															−0,31	0,34	8,40
															−0,21	0,34	8,45
18	Joseph, Keehn, Connolly, Wolfe, & Horowitz (2009)	M	12–18y	100–120	100–120	21	M	12–18y	100–120	100–120	21	VS	RT	L	0,83	0,32	9,66
19a	Kaland, Mortensen, & Smith (2007)	M	12–18y	100–120	100–120	13	M	12–18y	100–120	100–120	13	BDT	Acc	L (G)	0,39	0,40	6,38
															0,45	0,40	6,34
19b	Kaland, Mortensen, & Smith (2007)	M	12–18y	100–120	100–120	13	M	12–18y	100–120	100–120	13	EFT	RT	L (G)	−0,19	0,39	6,47
20	Keehn et al. (2009)	/	12–18y	100–120	100–120	12	/	12–18y	100–120	100–120	11	EFT	RT	L (G)	0,89	0,44	5,23
21a	Kuschner, Bodner, & Minshew (2009)	M	6–12y	100–120	100–120	23	M	6–12y	70–100	100–120	26	BDT	Acc	G (L)	0,16	0,29	12,16
								18–35y	70–100	70–100	23				0,48	0,30	11,17
		M	18–35y	100–120	70–100	14	M	6–12y	70–100	100–120	26		Acc	G (L)	−0,47	0,34	8,88
								18–35y	70–100	70–100	23				−0,23	0,34	8,65
21b	Kuschner, Bodner, & Minshew (2009)	M	6–12y	100–120	100–120	23	M	6–12y	70–100	100–120	26	DT	Acc	G (L)	0,27	0,29	12,09
					70–100			18–35y	70–100	100–120	23				−0,49	0,30	11,17
		M	18–35y	100–120	100–120	14	M	6–12y	70–100	70–100	26		Acc	G (L)	0,19	0,33	9,06
					70–100			18–35y	70–100	70–100	23				−0,53	0,34	8,43
22	Lee et al. (2007)	M/F	6–12y	/	100–120	17	M/F	6–12y	/	100–120	14	EFT	Acc	L (G)	−0,23	0,36	7,63

(*table continues*)

Table 2 (*continued*)

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
													RT	L(G)	−0,29	0,36	7,60
23	Loth, Gomez, & Happé (2008)	M/F	18–35y	100–120	100–120	15	M/F	18–35y	100–120	100–120	15	D	Acc	L(G)	−0,78	0,38	6,97
															−0,22	0,37	7,46
															0,56	0,37	7,22
													RT	L(G)	−0,78	0,38	6,96
															−0,03	0,37	7,50
															0,35	0,37	7,39
24	Loth, Gomez, & Happé (2010)	M/F	18–35y	100–120	100–120	14	M/F	18–35y	100–120	100–120	14	D	Acc	L(G)	−0,55	0,39	6,74
															−1,10	0,41	6,08
25	Maekawa et al. (2011)	M/F	18–35y	/	/	11	M/F	18–35y	/	/	11	D	Acc	L	0,07	0,43	5,50
													RT	L	0,90	0,45	4,99
26	Malisza et al. (2011)	M/F	6–12y	/	70–100	7	M/F	12–18y	/	/	9	EFT	Acc	L(G)	−0,97	0,53	3,53
		M/F	6–12y	/	70–100	8							RT	L(G)	0,24	0,49	4,21
27	Maljaars, Noens, Scholte, Verpoorten, & van Berckelaer-Onnes (2011)	M/F	12–18y	40–70	40–70	72	M/F	12–18y	40–70	40–70	68	D	Acc	L	3,66	0,28	13,06
															6,96	0,45	4,96
														G(L)	2,71	0,23	18,22
28	Manjaly et al. (2007)	/	12–18y	100–120	100–120	12	/	12–18y	100–120	100–120	12	EFT	Acc	L(G)	−1,98	0,50	4,03
													RT	L(G)	0,12	0,41	5,99
29	Mitchell, Mottron, Soulieres, & Ropar (2010)	M/F	18–35y	100–120	100–120	18	M/F	18–35y	100–120	100–120	18	VI	Acc	L(G)	−0,61	0,34	8,60
30	Mottron, Belleville, & Menard (1999)	M/F	18–35y	100–120	100–120	10	M/F	18–35y	100–120	100–120	11	VI	Acc	G(L)	−0,34	0,44	5,17
															0,91	0,46	4,74
														L(G)	−0,23	0,44	5,20
															−0,56	0,45	5,04
31	Mottron, Burack, Iarocci, Belleville, & Enns (2003)	M/F	12–18y	/	100–120	12	M/F	12–18y	/	100–120	12	HF	RT	L(G)	−2,70	0,56	3,14
														G(L)	−5,16	0,85	1,39
32	Mottron, Burack, Stauder, & Robaey (1999)	M/F	12–18y	100–120	100–120	11	M/F	12–18y	100–120	100–120	11	HF	RT	L(G)	−1,96	0,52	3,72
														G(L)	−1,58	0,49	4,19
33	Nakahachi et al. (2008)	M/F	18–35y	/	70–100	10	M/F	18–35y	/	/	26	D	Acc	L	−1,41	0,41	6,02
														L(G)	−0,76	0,38	6,83
34	O'Riordan (2000)	/	6–12y	70–100	70–100	11	/	6–12y	70–100	70–100	12	VS	RT	L	1,02	0,44	5,08
														G(L)	0,94	0,44	5,17
35	O'Riordan, Plaisted, Driver, & Baron-Cohen (2001)	/	6–12y	70–100	70–100	12	/	6–12y	70–100	70–100	12	VS	RT	L	0,00	0,41	6,00
														G(L)	1,02	0,43	5,31
36	Pellicano, Gibson, Maybery, Durkin, & Badcock (2005)	M/F	6–12y	100–120	100–120	20	M/F	6–12y	100–120	100–120	20	EFT	RT	L(G)	7,31	0,88	1,30

Table 2 (*continued*)

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
37	Plaisted, Dobler, Bell, & Davis (2006)	/	6–12y	100–120	100–120	21	/	6–12y	100–120	100–120	22	HF	RT	L(G)	0,56	0,31	10,34
															−1,09	0,33	9,36
															−0,48	0,31	10,44
															−0,43	0,31	10,50
														G(L)	0,65	0,31	10,20
															−1,15	0,33	9,23
															0,43	0,31	10,50
															0,00	0,31	10,74
38	Plaisted, O'Riordan, & Baron-Cohen (1998)	/	6–12y	/	/	8	/	6–12y	/	/	8	VS	RT	L	0,64	0,51	3,81
															0,32	0,50	3,95
															0,06	0,50	4,00
														G(L)	0,51	0,51	3,88
															1,06	0,53	3,51
															0,86	0,52	3,66
39	Plaisted, Saksida, Alcantara, & Weisblatt (2003)	/	6–12y	70–100	70–100	12	/	6–12y	70–100	70–100	12	D	Acc	L	−0,77	0,42	5,58
														G(L)	0,00	0,41	6,00
40	Plaisted, Swettenham, & Rees (1999)	/	6–12y	70–100	70–100	17	/	6–12y	70–100	70–100	17	HF	RT	L(G)	0,00	0,34	8,50
														G(L)	0,00	0,34	8,50
														L	0,00	0,34	8,50
														G	0,00	0,34	8,50
41	Planche & Lemonnier (2011)	M/F	6–12y	70–100	70–100	15	M/F	6–12y	100–120	100–120	15	BDT	Acc	L(G)	0,45	0,37	7,32
		M/F	6–12y	100–120	100–120	15	M/F	6–12y	100–120	100–120	15	BDT	Acc	L(G)	−0,83	0,38	6,91
42a	Pring, Ryder, Crane, & Hermelin (2010)	M/F	18–35y	70–100	70–100	9	M/F	12–18y	100–120	100–120	9	BDT	Acc	L(G)	−0,99	0,50	4,01
								18–35y							0,12	0,47	4,49
								12–18y							−2,79	0,66	2,28
								18–35y							−1,93	0,57	3,07
42b	Pring, Ryder, Crane, & Hermelin (2010)	M/F	18–35y	70–100	70–100	9	M/F	12–18y	100–120	100–120	9	EFT	RT	L(G)	−0,70	0,49	4,24
								18–35y							−0,03	0,47	4,50
								12–18y							−1,02	0,50	3,99
								18–35y							−0,79	0,49	4,17
43	Rinehart, Bradshaw, Moss, Brereton, & Tonge (2001)	M/F	6–12y	/	70–100	12	M/F	6–12y	/	/	12	HF	RT	L(G)	−0,60	0,42	5,74
		M/F	12–18y		100–120	12	M/F	12–18y			12				−0,77	0,42	5,59
44	Ring et al. (1999)	M/F	18–35y	100–120	100–120	6	M/F	18–35y	100–120	100–120	12	EFT	Acc	L(G)	0,56	0,51	3,87
45a	Ropar & Mitchell (2001)	M/F	12–18y	/	/	19	M/F	6–12y	/	/	19	BDT	Acc	L(G)	−0,43	0,33	9,29
								6–12y			18				−0,74	0,34	8,66
								12–18y			20				0,97	0,34	8,72
		M/F	6–12y	/	/	11	M/F	6–12y	/	/	19	BDT	Acc	L(G)	0,30	0,38	6,90
								6–12y			18				−0,01	0,38	6,83
								12–18y			20				2,10	0,46	4,71
45b	Ropar & Mitchell (2001)	M/F	12–18y	/	/	19	M/F	6–12y	/	/	20	EFT	Acc	L(G)	1,19	0,35	8,27
								6–12y			19				0,99	0,34	8,47
								12–18y			18				−0,61	0,34	8,83
		M/F	6–12y	/	/	11	M/F	6–12y	/	/	20	EFT	Acc	L(G)	1,56	0,42	5,55
								6–12y			19				1,36	0,42	5,73

(*table continues*)

Table 2 (*continued*)

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
								12–18y			18				−0,21	0,38	6,79
45b	Ropar & Mitchell (2001)	M/F	12–18y	/	/	19	M/F	6–12y	/	/	20	EFT	RT	L (G)	1,28	0,35	8,10
								6–12y			19				1,11	0,35	8,22
								12–18y			18				−0,48	0,33	8,99
		M/F	6–12y	/	/	11	M/F	6–12y	/	/	20	EFT	RT	L (G)	1,63	0,43	5,44
								6–12y			19				1,38	0,42	5,71
								12–18y			18				−0,13	0,38	6,81
46a	Rouse, Donnelly, Hadwin, & Brown (2004)	M	6–12y	/	/	11	M	6–12y	/	/	15	VI	Acc	L (G)	−0,20	0,40	6,31
															0,24	0,40	6,30
															2,85	0,56	3,18
															3,69	0,65	2,38
													RT	L (G)	−0,97	0,42	5,69
															1,13	0,43	5,49
															2,07	0,49	4,16
															−0,72	0,41	5,97
													Acc	L (G)	−2,67	0,54	3,40
															−1,33	0,44	5,22
															−1,22	0,43	5,38
															−0,58	0,41	6,10
													RT	L (G)	−3,36	0,61	2,67
															−0,12	0,40	6,34
															−3,83	0,66	2,27
															−0,72	0,41	5,96
46b	Rouse, Donnelly, Hadwin, & Brown (2004)	M	6–12y	/	/	10	M	6–12y	/	/	12	VI	Acc	L (G)	1,04	0,46	4,81
															1,72	0,50	4,00
							M	6–12y	/	/	14	VI	Acc	L (G)	−0,67	0,43	5,53
															1,58	0,47	4,48
							M	6–12y	/	/	12	VI	RT	L (G)	1,58	0,49	4,16
															1,86	0,51	3,81
							M	6–12y	/	/	14	VI	RT	L (G)	−2,24	0,53	3,62
															−0,09	0,41	5,83
47	Scherf, Luna, Kimchi, Minshew, & Behrmann (2008)	M	6–12y	100–120	100–120	15	M/F	6–12y	100–120	100–120	15	HF	RT	G (L)	−0,44	0,37	7,32
														G	−0,74	0,38	7,02
							M	12–18y	100–120	100–120	15	HF	RT	G (L)	−1,57	0,42	5,74
														G	−1,79	0,43	5,36
							M	18–35y	/	/	9	HF	RT	G (L)	−2,10	0,52	3,71
														G	−2,31	0,54	3,46
		M	12–18y	100–120	100–120	15	M/F	6–12y	100–120	100–120	15	HF	RT	G (L)	0,90	0,38	6,82
														G	1,11	0,39	6,50
							M	12–18y	100–120	100–120	15	HF	RT	G (L)	−0,19	0,37	7,47
														G	−0,01	0,37	7,50
							M	18–35y	/	/	9	HF	RT	G (L)	−0,87	0,44	5,17
														G	−0,84	0,44	5,20
		M	18–35y	100–120	100–120	9	M/F	6–12y	100–120	100–120	15	HF	RT	G (L)	0,79	0,44	5,24
														G	0,86	0,44	5,18

Table 2 (*continued*)

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
47	Scherf, Luna, Kimchi, Minshew, & Behrmann (2008)	M	18–35y	100–120	100–120	9	M	12–18y	100–120	100–120	15	HF	RT	G(L)	−0,73	0,43	5,30
														G	−0,41	0,43	5,51
							M	18–35y	/	/	9	HF	RT	G(L)	−2,01	0,58	2,99
														G	−1,55	0,54	3,46
		M	6–12y	100–120	100–120	15	M/F	6–12y	100–120	100–120	15	HF	RT	L(G)	−0,55	0,37	7,23
														L	−0,62	0,37	7,16
							M/F	12–18y	100–120	100–120	15	HF	RT	L(G)	−1,43	0,41	5,98
														L	−1,75	0,43	5,43
							M	18–35y	/	/	9	HF	RT	L(G)	−1,33	0,46	4,66
														L	−1,67	0,49	4,24
		M/F	12–18y	100–120	100–120	15	M/F	6–12y	100–120	100–120	15	HF	RT	L(G)	0,70	0,38	7,06
														L	0,74	0,38	7,02
							M/F	12–18y	100–120	100–120	15	HF	RT	L(G)	−0,45	0,37	7,31
														L	−0,38	0,37	7,37
							M	18–35y	/	/	9	HF	RT	L(G)	−0,53	0,43	5,45
														L	−0,55	0,43	5,43
		M/F	18–35y	100–120	100–120	9	M/F	6–12y	100–120	100–120	15	HF	RT	L(G)	0,62	0,43	5,38
														L	0,69	0,43	5,32
							M/F	12–18y	100–120	100–120	15	HF	RT	L(G)	−1,00	0,45	5,03
														L	−0,95	0,44	5,09
							M	18–35y	/	/	9	HF	RT	L(G)	−1,11	0,51	3,90
														L	−1,09	0,51	3,92
48a	Schlooz et al. (2006)	M	6–12y	100–120	100–120	12	M	6–12y	/	/	12	DT	Acc	G(L)	−0,87	0,43	5,48
															−0,65	0,42	5,70
48b	Schlooz et al. (2006)	M	6–12y	100–120	100–120	12	M	6–12y	/	/	12	EFT	RT	L(G)	0,25	0,41	5,95
															0,05	0,41	6,00
													Acc	L(G)	0,06	0,41	6,00
															−0,16	0,41	5,98
49	Shah & Frith (1993)	M/F	18–35y	70–100	70–100	10	M/F	12–18y	/	100–120	17	BDT	RT	L(G)	0,14	0,40	6,28
							M/F	6–12y	/	100–120	16				0,61	0,41	5,89
		M/F	18–35y	70–100	40–70	10	M/F	6–12y	/	100–120	16				0,30	0,41	6,09
							M/F	12–18y	/	100–120	17				−0,25	0,40	6,25
		M/F	18–35y	70–100	70–100	10	M/F	12–18y	/	100–120	17			L	−0,14	0,40	6,28
							M/F	6–12y	/	100–120	16				−0,15	0,40	6,14
		M/F	18–35y	70–100	40–70	10	M/F	6–12y	/	100–120	16				0,80	0,42	5,72
							M/F	12–18y	/	100–120	17				−0,97	0,42	5,68
50	Sheppard, Ropar, & Mitchell (2009)	M/F	12–18y	70–100	70–100	19	M/F	12–18y	70–100	70–100	18	VI	Acc	G(L)	0,12	0,33	9,23
														G	0,02	0,33	9,24
														G(L)	−0,26	0,33	9,17
														G	−0,18	0,33	9,21
														G(L)	−0,27	0,33	9,16
														G	0,00	0,33	9,24
														G(L)	0,00	0,33	9,24
														G	−0,40	0,33	9,06
51	Soulières, Zeffiro, Girard, & Mottron (2011)	M/F	12–18y	100–120	100–120	16	M/F	12–18y	100–120	100–120	16	CZ	Acc	L(G)	−1,07	0,38	6,99

(*table continues*)

Table 2 (*continued*)

		Participants with ASD					Participants without ASD					Task			Results		
Nr	Study	Sex	Age	NVIQ	FSIQ	*N*	Sex	Age	NVIQ	FSIQ	*N*	Type	Measure	Level of visual processing	*g*	*SE*(*g*)	*P*
52	Soulières, Mottron, Saumier, & Larochelle (2006)	M/F	18–35y	/	100–120	16	M/F	12–18y	/	100–120	16	CZ	Acc	G	0,05	0,35	8,00
53	Spencer et al. (2012)	M/F	12–18y	/	100–120	38	M/F	12–18y	/	100–120	40	EFT	Acc	L(G)	−0,38	0,23	19,15
													RT	L(G)	−0,01	0,23	19,49
54	Tsatsanis et al. (2011)	M/F	12–18y	100–120	100–120	50	M/F	12–18y	100–120	100–120	49	DT	Acc	G(L)	−0,28	0,20	24,50
55	Vladusich, Olu Lafe, Kim, Tager-Flusberg, & Grossberg (2010)	M	18–35y	100–120	100–120	19	M	18–35y	100–120	100–120	21	CZ	Acc	G(L)	−1,20	0,34	8,46
		M	18–35y	100–120	100–120	13	M	18–35y	100–120	100–120	18				−0,03	0,36	7,55
56	Wang, Mottron, Peng, Berthiaume, & Dawson (2007)	M/F	12–18y	40–70	40–70	15	M/F	12–18y	40–70	40–70	15	HF	RT	L(G)	0,75	0,38	7,01
															−0,74	0,38	7,01
															−0,29	0,37	7,42
														G(L)	−3,04	0,54	3,48
															−2,44	0,48	4,30
															−1,35	0,40	6,11
														L(G)	−1,98	0,45	5,04
															−4,17	0,65	2,36
															−2,62	0,50	4,03
														G(L)	−6,84	0,96	1,09
															−4,23	0,66	2,32
															−3,22	0,55	3,27
													Acc	L(G)	2,11	0,46	4,82
															1,67	0,42	5,56
															2,05	0,45	4,91
														G(L)	−0,82	0,38	6,92
															−0,78	0,38	6,96
56	Wang, Mottron, Peng, Berthiaume, & Dawson (2007)	M/F	12–18y	40–70	40–70	15	M/F	12–18y	40–70	40–70	15	HF	Acc	G(L)	0,72	0,38	7,04
														L(G)	1,73	0,43	5,46
															−1,50	0,41	5,85
															−1,15	0,39	6,44
														G(L)	−0,51	0,37	7,26
															−0,90	0,38	6,81
															−1,29	0,40	6,20
													RT	L(G)	−2,26	0,47	4,58
															−1,70	0,43	5,51
														G(L)	−3,38	0,57	3,09
															−3,91	0,62	2,58
													Acc	L(G)	1,20	0,40	6,36
															2,75	0,51	3,85
														G(L)	1,27	0,40	6,24
															−0,43	0,37	7,33

Note. M = all male participant group; F = all female participant group; M/F = mixed participant group; *N* = number of participants; BDT = block design task; CZ = categorization task; D = discrimination; DT = drawing task; EFT = embedded figure task; HF = hierarchical letters or hierarchical figures; VI = visual illusion task; VS = visual search task; RT = reaction time; Acc = accuracy; L = local information with none or consistent global-level information; L(G) = local information with inconsistent global-level information; G = global information with none or consistent local-level information; G(L) = global information with inconsistent local-level information; y = age in years; *g* = Hedges' *g* effect size; *SE*(*g*) = standard error of the effect size estimate; *P* = precision of effect size; estimated as the inverse of the sampling variance of the effect size estimate; / = indicates information was not available.

deviation of the observed effect size from the population effect size for outcome j in study k. All three residuals, $v_{.k}$, u_{jk}, e_{jk}, are assumed to be independently normally distributed with zero mean. Because the sampling variance (i.e., the squared standard error) for each g_{jk} has been estimated using reported data before conducting the meta-analyses, only the mean effect size β_0, the between-study variance σ_v^2 and the within-study variance σ_u^2 are estimated in the meta-analysis. This model was extended by including each of the coded study characteristics (or specific combinations of these) as predictors, as in an ordinary regression model, in order to investigate their influence. The variance components of the model including predictor variables refer to the unexplained variance.

Parameters of the three-level meta-analytic models are estimated using the restricted maximum likelihood estimation, implemented in the mixed procedure from the general statistical package SAS (version 9.3; SAS Publishing, 2011). For exploring possible publication bias and its impact, we used funnel plots and applied the trim-and-fill method of Duval and Tweedie (2000) as implemented in CMA (version 2.0; Borenstein, Hedges, Higgins, & Rothstein, 2005). All significance tests were conducted with a significance level of 5%.

Results

This meta-analysis examined 56 articles, which tested about 1,000 ASD participants. Forty articles reported summary data on group differences in terms of accuracy (including error rates or threshold values) and 35 articles in terms of RT differences. Of the 64 experiment included, 19 experiments covered embedded figures, 10 block design, nine hierarchical letters or hierarchical figures, seven visual illusion(s), seven visual search, six visual discrimination, four a drawing task, and two experiments covered a categorization task. Mean age ranged from 6.5 to 34.5 years, average FSIQ ranged from 62 to 119, average NVIQ ranged from 67 to 118, percentage of females ranged from 0% to 100% (M = 13%, SD = 17%). Sample sizes ranged from 6 to 50.

For a random effect analysis of the overall effect size, we found a mean effect size of −0.232, with 95% confidence limits from −0.372 to −0.093. A negative effect indicates worse performance for the ASD group, that is, lower accuracy or higher RT. This is a small effect size (Cohen, 1988) and indicates no clear difference in performance present between the ASD group and the typically developing group. Both the within-study variance σ_u^2 (estimate = 1.6298, z = 3.29, p = .0005) as the between-study variance σ_v^2 (estimate = .5533, z = 3.68, p = .0001) are significant, indicating that effect sizes varied across and within studies. Such variability stresses the importance of moderator analyses that reveal which moderators rule the diversity.

Evaluation of Publication Bias

Publication bias (i.e., the tendency to report only statistically significant results) can have serious implications for meta-analysis research. As an initial test of publication bias, we plotted the effect sizes against the standard error of effect size in a funnel plot (Egger, Davey Smith, Schneider, & Minder, 1997). As the funnel plot showed a slight asymmetry, which might indicate publication bias, we performed the Begg and Mazumdar (1994) rank correlation test. A correlation between sample size and observed effect size indicates publication bias, as it could mean that significant effects in the expected direction are more likely to be published: For small studies only large effect sizes will be statistically significant, whereas for larger studies also relatively small effect sizes can be statistically significant. Kendall's tau, used to assess Begg and Mazumdar's rank correlation test, is −.156, $p < .0005$, which does indicate a risk for publication bias. To further explore the impact of possible publication bias, we implemented the Duval and Tweedie's (2000) trim and fill method. Under the random effect model the Trim and Fill method suggested 50 observed effect sizes to be missing on the left side (negative findings) and no effect sizes to be missing on the right side (positive findings) (see Figure 2 and Figure 3). Repeating our standard random effect analysis with these filled studies gave an estimated overall effect size of −0.651, with 95% confidence limits from −0.815 to −0.487. The results of both the rank correlation test as well as the Trim and Fill method suggest that, in case of a real publication bias, the population effect would be even larger than the effect estimated based on the effect sizes reported in the literature, that is, a worse overall performance of the ASD group compared to the typically developing group.

Impact of Moderator Variables

We considered the impact of six moderator variables, that is, level of visual processing, type of performance measure, type of task, gender, age, and IQ, as such moderator analyses allow us to answer under which specific conditions individuals with ASD do or do not show a certain bias or deficit when compared to typically developing individuals.

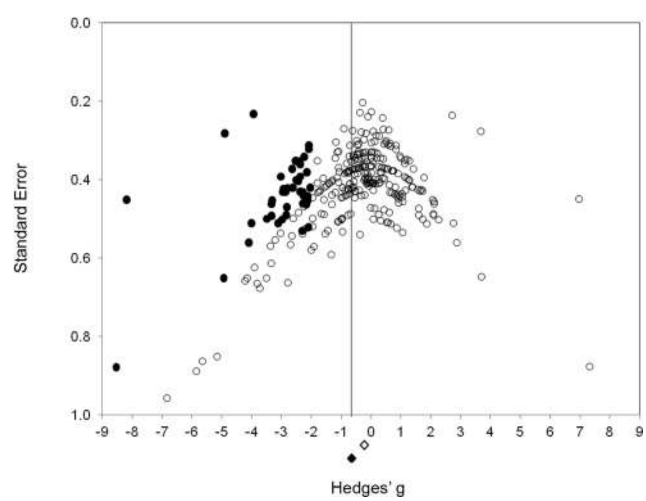

Figure 2. This funnel plot displays the mean effect size as criterion variable and the standard error as predictor variable. Open circles refer to an actual data point in the meta-analysis. Filled circles indicate studies inferred in the trim-and-fill analysis. The open diamond indicates the population effect as estimated based on the effect sizes included in the meta-analysis. The filled diamond indicates the population effect as inferred in the trim-and-fill analysis. Negative effect sizes indicate worse performance for individuals with ASD compared with TD, positive effect sizes indicate better performance for individuals with ASD compared with TD. The vertical line indicates the position of the overall effect size in the random effect analysis, with a mean effect size of −0.232, with 95% confidence limits from −0.372 to −0.093.

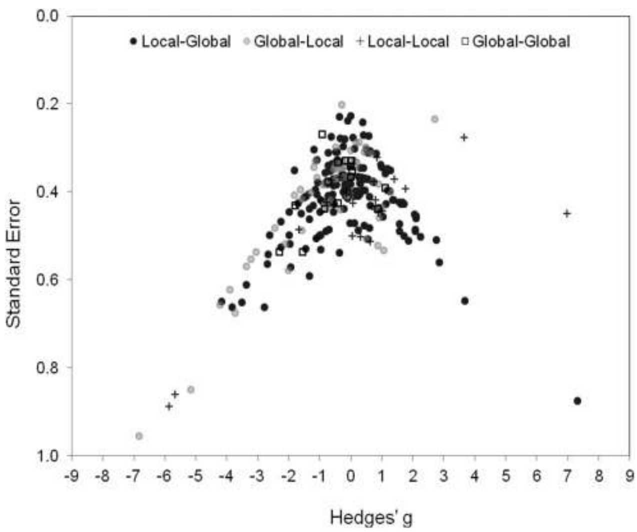

Figure 3. This funnel plot displays the mean effect size as criterion variable and the standard error as predictor variable. Each effect size is labeled as to what kind of comparison it relates to with respect to level(s) of visual processing. Negative effect sizes indicate worse performance for individuals with ASD compared with TD, positive effect sizes indicate better performance for individuals with ASD compared with TD.

Disentanglement of local–global in ASD. To examine the effect of level of visual processing, that is, local-level versus global-level, two (nested) analyses were conducted. A first, general analysis, taking into account the level of visual processing participants were instructed to attend to (see Table 1), revealed a similar performance for both participant groups for local visual processing as well as an overall diminished performance of ASD individuals for global order processing (see Table 3). However, although commonly used, such analysis takes into account solely what participants were asked to focus on and discards the fact that other, task-irrelevant information, might be present and might interfere with how the task-relevant information is being processed. For that reason, a second, more refined analysis was conducted, taking into account not only the level of visual processing participants had to attend to in order to complete the task, but also what level(s) of visual processing information were present, whether they were relevant to the task or not (see Table 1). From the four resulting combinations only one yielded a group difference: a strong diminished performance effect for ASD individuals was revealed for tasks that required global processing while more detailed, task irrelevant, inconsistent local information was also present (see Table 3; $g = -0.52$, $t(83.5) = -2.13$, $p = .0358$). It is important to note how this second analysis changes the implications one would otherwise connect to the results of the first analysis. Rather than an overall diminished performance for ASD on global processing, results show the presence of an interference effect of present local-level information on global processing, suggesting that the default processing style of people with ASD is more local.

Timing is everything. To investigate the effect of the type of performance measure, that is, accuracy versus RT, we compared 39 accuracy scores with 35 RT ratings on local–global visual processing across tasks. Although results indicate that individuals with ASD perform as well as typically developing individuals when performance is measured in terms of accuracy (or error) rates (i.e., the observed better performance of individuals with ASD with regard to accuracy is statistically not significant), a significantly diminished performance is present in ASD when performance is measured by RT (see Table 4). Overall, individuals with ASD perform as accurate as typically developing individuals but they are significantly slower than typically developing individuals. Smaller group differences are obtained when taking into account accuracy scores or RT data on specific (subgroups) of tasks (see Task at Hand).

Global perception takes time. One important question to ask is how these effects of level of visual processing and measure of performance interact with each other. An analysis that combined level of visual processing and measure of performance did not yield any overall group differences, other than a significant group difference in favor of the typically developing group for the case that participants were presented with a RT task requiring them to attend to the global level, while inconsistent information at the local level was present (see Table 5; $g = -0.98$, $t(123) = -3.41$, $p = .0009$). This effect is not obtained when measuring accuracy

Table 3
The Level of Visual Processing as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Primary (task-relevant) level of processing		(1, 233)	5.90	.0159*				
Local	193				−0.01	40.8	−0.06	.9487
Global	87				−0.47	74.5	−2.03	.0462*
Primary (task-relevant) and secondary (task-irrelevant) level(s) of processing		(3, 230)	2.28	.0797				
Local–Local	30				−0.18	140.0	−0.60	.5500
Local–Global	163				0.03	46.6	0.15	.8823
Global–Global	16				−0.30	204.0	−0.78	.4350
Global–Local	71				−0.52	83.5	−2.13	.0358*

Note. Whereas "Local–Local" and "Global–Global" refer to instances where the secondary (task-irrelevant) level of visual processing is absent or nonconflicting, "Local–Global" and "Global–Local" refer to instances where the secondary (task-irrelevant) level of visual processing is present and conflicting with the primary level of visual processing (also see Table 1); data displayed include both accuracy and reaction time data; ES = effect sizes; *g* refers to Hedges' *g* effect size.
* $p < .05$.

Table 4
Performance Measure as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Measure of performance		(1, 235)	9.80	.0020**				
Accuracy	130				0.13	48.2	0.60	.5485
Reaction time	150				−0.43	51.4	−2.02	.0489*

Note. ES = effect size; *g* refers to Hedges' *g* effect size.
* $p < .05$. ** $p < .005$.

rates in such condition. As this interaction effect is not present in the noninterference conditions (where only information is present at one level) nor in the other interference condition (where both local and global information is present, but only the local-level information is task-relevant), the interference appears to be due to the presence of the incongruent local elements, which cause a delay in grasping the gist by ASD individuals. Note that this interaction effect does not entail an enhanced performance on local-level visual information nor a deficit in getting the global-level visual information as such. There is no group difference for perceiving local order and no differences in terms of accuracy rates for perceiving global order, but merely an effect of interference of the presence of local element on the speed with which ASD individuals are able to grasp global-level visual information.

The task at hand. To examine the effect of a specific task or paradigm, we analyzed the overall impact of task as moderator variable as well as the impact of each task individually (where possible, see below). The analysis on task as moderator variable, did not indicate overall task-dependency: The size of the group difference did not differ significantly depending on the particular task at hand (see Table 6), $F(7, 71.80) = 0.86$, $p = .55$. This should not come as a surprise, as most often within one task, variation exists in whether researchers focused on accuracy or RT, or on local or global visual processing. Such variability within on task category makes it more difficult to find general task-dependent group differences.

However, when analyzing interaction effects between the tasks and the levels of visual processing or between the tasks and the type of performance measures, interesting effects were obtained. Group differences, when present, varied between tasks, when taking into account the type of processing measure or the level of visual processing (Table 1, see also Table 7 and Table 8, respectively). Given these interaction effects, we will discuss the effects for each task separately and report several smaller task-specific meta-analyses. Whereas an interaction between task and type of performance is interesting but no reason for methodological concern, a qualitatively different influence of level of visual processing depending on the task that is presented, does raise doubts on the existence of a standard operationalization of the concepts of "local" and "global" (as anticipated on the basis of the study by Milne & Szczerbinski, 2009). Note that analyses on two or less effect sizes are not reported (i.e., a separate analysis for categorization or an accuracy analysis for visual search).

Hierarchical figures. With regard to hierarchical figures or letters, interesting results were obtained. The group differences that are present in the data are not only clearly mediated by the type of measure that was used to assess performance, but also by the level of visual processing that was tapped into. On the one hand, ASD participants performed overall slower ($g = -1.15$, $t(6.96) = -2.76$, $p = .028$) than typically developing individuals when presented with a hierarchical stimulus with two levels present. A large and significant group difference was present when

Table 5
The Effect of the Level of Visual Processing and the Type of Performance Measure Used

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Measure of performance		(1, 213)	2.60	.1082				
Level of visual processing participants can attend to		(3, 225)	1.76	.1560				
Interaction		(3, 225)	1.01	.3908				
Accuracy × Global–Global	6				−0.15	177.0	−0.23	.8205
Accuracy × Global–Local	33				0.03	132.0	0.10	.9224
Accuracy × Local–Global	84				0.23	63.7	1.01	.3166
Accuracy × Local-Local	7				−0.21	181.0	−0.35	.7301
RT × Global–Global	10				−0.52	236.0	−1.13	.2616
RT × Global–Local	38				−0.98	123.0	−3.41	.0009**
RT × Local–Global	79				−0.22	65.1	−0.94	.3494
RT × Local–Local	23				−0.40	163.0	−1.17	.2433

Note. Whereas "Local–Local" and "Global–Global" refer to instances where the secondary (task-irrelevant) level of visual processing is absent or nonconflicting, "Local-Global" and "Global-Local" refer to instances where the secondary (task-irrelevant) level of visual processing is present and conflicting with the primary level of visual processing (also see Table 1); RT = reaction time; ES = effect sizes; *g* refers to Hedges' *g* effect size.
** $p < .001$.

Table 6
Type of Task as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Task		(7, 71.8)	0.86	.5452				
BDT	34				0.00	90.7	0.01	.9937
CZ	4				−0.55	57.1	−0.63	.5343
D	25				0.19	70.4	0.42	.6738
DT	8				−0.36	170.0	−0.65	.5185
EFT	51				0.30	66.1	1.06	.2952
HF	93				−0.77	34.1	−1.80	.0807
VI	46				−0.14	37.3	−0.28	.7801
VS	19				−0.36	50.8	−0.71	.4811

Note. Data displayed include both accuracy and reaction time data. BDT = block design task; CZ = categorization task; D = discrimination; DT = drawing task; EFT = embedded figure task; HF = hierarchical letters or hierarchical figures; VI = visual illusion task; VS = visual search task; ES = effect sizes; *g* refers to Hedges' *g* effect size.

participants were asked to name the global figure and local-level information was incongruent ($g = 1.53$, $t(8.92) = -3.29$, $p = .01$). In all three other conditions, a similar, but only marginally significant trend was present (*p*-values between .05 and .06). On the other hand, ASD participants were generally more accurate ($g = 1.47$, $t(16.7) = 2.78$, $p = .013$) than typically developing individuals, and this group difference was largest when looking at the condition in which participants were asked to name the local letter and incongruent information was present at the global level ($g = 2.04$, $t(20.7) = 3.48$, $p = .002$). These results point to a double interference effect: Although participants with ASD process a hierarchical stimulus slower when having to attend to the global-level and ignore the (in)congruent local-level, they are more accurate than typically developing individuals when having to attend to the local-level and ignore the incongruent global-level input.

Visual search. With regard to visual search task, the analysis yielded rather unexpected findings. Contrary to what is commonly thought about ASD performance in search, results showed no group difference between ASD individuals and typically developing individuals in terms of RT (RT: $g = .38$, $t(5.21) = 0.75$, $p = .48$). The ASD group did not prove to be faster at visual search than the typically developing group.

Block design, discrimination, and visual illusions. Separate analyses yielded very similar results for block design, discrimination and visual illusion paradigms. For all three, data were available in terms of accuracy as well as RT, and on local-level as well as global-level processing. However, for neither of these tasks did the analysis yield any group differences. Performance of ASD individuals did not differ from performance of typically developing individuals; not in terms of main effects, nor in terms of interaction effects.

Embedded figures. With regard to data of the embedded figures task, our analysis was restricted to local-level processing as no global-level processing is actively assessed. Contrary to what is often thought, results showed no group difference between ASD individuals and typically developing individuals; not in terms of accuracy rates, nor in terms of RT (accuracy: $g = 0.17$, $t(14.8) =$

Table 7
Interaction Effects Between the Task at Hand and the Measure of Performance Used

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Measure		(1, 150)	9.89	.0020**				
Task		(6, 80.3)	0.99	.4374				
Task × Measure		(4, 196)	9.21	<.0001***				
Accuracy × BDT	25				0.16	111.0	0.51	.6139
Accuracy × D	17				0.23	76.6	0.51	.6150
Accuracy × DT	8				−0.27	164.0	−0.54	.5882
Accuracy × EFT	23				0.24	109.0	0.74	.4621
Accuracy × HF	17				1.33	96.0	2.72	.0077*
Accuracy × VI	34				0.02	40.6	0.05	.9629
RT × BDT	9				−0.42	55.4	−0.48	.6323
RT × D	8				0.02	152.0	0.03	.9755
RT × EFT	28				0.49	102.0	1.65	.1016
RT × HF	76				−1.22	36.6	−3.06	.0041**
RT × VI	12				−0.64	97.6	−1.08	.2830
RT × VS	17				0.37	52.4	0.75	.4595

Note. BDT = block design task; D = discrimination; DT = drawing task; EFT = embedded figure task; HF = hierarchical letters or hierarchical figures; VI = visual illusion task; VS = visual search task; RT = reaction time; ES = effect sizes; *g* refers to Hedges' *g* effect size.
$^{*}p < .05$. $^{**}p < .005$. $^{***}p < .0001$.

Table 8
Interaction Effects Between the Task at Hand and the Level of Visual Processing

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Task		(6, 69.7)	0.76	.6061				
Level of visual processing participants can attend to		(3, 184)	0.11	.9552				
Interaction		(7, 190)	0.63	.7318				
BDT × Global–Local	4				−0.23	127.0	−0.24	.8137
BDT × Local–Global	26				0.03	87.3	0.08	.9330
BDT × Local–Local	4				−0.25	209.0	−0.30	.7634
D × Global–Local	10				−0.16	166.0	−0.27	.7886
D × Local–Global	9				0.04	45.7	0.04	.9699
D × Local–Local	6				0.96	95.8	1.36	.1777
DT × Global–Local	7				−0.40	99.7	−0.56	.5768
EFT × Local–Global	51				0.27	55.0	0.89	.3765
HF × Global–Global	10				−0.81	92.2	−1.35	.1813
HF × Global–Local	35				−1.22	39.8	−2.58	.0138*
HF × Local–Global	38				−0.49	37.1	−1.08	.2876
HF × Local–Local	10				−0.81	91.8	−1.35	.1794
VI × Global–Global	4				0.12	85.6	0.11	.9116
VI × Global-Local	6				0.21	69.8	0.24	.8079
VI × Local–Global	36				−0.21	45.3	−0.38	.7048
VS × Global–Local	7				−0.09	83.0	−0.14	.8919
VS × Local–Local	10				−0.45	74.5	−0.78	.4371

Note. Data displayed include both accuracy and reaction time data. Whereas "Local–Local" and "Global–Global" refer to instances where the secondary (task-irrelevant) level of visual processing is absent or nonconflicting, "Local–Global" and "Global–Local" refer to instances where the secondary (task-irrelevant) level of visual processing is present and conflicting with the primary level of visual processing (also see Table 1); BDT = block design task; D = discrimination; DT = drawing task; EFT = embedded figure task; HF = hierarchical letters or hierarchical figures; VI = visual illusion task; VS = visual search task; ES = effect sizes; *g* refers to Hedges' *g* effect size.
* $p < .05$.

0.49, $p = .63$; RT: $g = .55$, $t(13) = 1.65$, $p = .12$). Overall, both groups performed similarly on this task.

Drawing. The analysis for drawing was restricted to accuracy rates for global-level processing, as the tasks are not employed to assess speed of drawing. Overall, the results did not yield a significant group difference, indicating that both groups performed equally accurate when having to draw or copy an existing figure ($g = -0.45$, $t(2.86) = -2.32$, $p = .10$). Note that this analysis includes the frequently used Rey-Osterrieth complex figure, but only includes its quantitative measure on the accuracy of the drawing, and not the qualitative measure or temporal process that is often recorded when administering this task.

Gender, age, and IQ. To examine the possible moderating effects of gender, age, NVIQ and FSIQ, multiple analyses were conducted (see Table 9, Table 10, Table 11, and Table 12).

Gender. A first analysis examined the impact of gender on overall group differences by including gender as a continuous variable (percentage of females in a participant group). Analyzing the impact of the percentage of females in the ASD participant group revealed no significant moderator effect (range = 0%–100%, $M = 11\%$, $SD = 14\%$; $F(1, 185) = 0.01$, $p = .92$). Conducting the same analysis for the percentage of females in the typically developing participant group did yield a significant moderator effect (range = 0%–100%, $M = 16\%$, $SD = 13\%$; $F(1, 169) = 6.06$, $p = .0148$), indicating better performance for the ASD group with increasing percentage of females in the typically developing participant group. A second analysis included gender of both participant groups as a categorical variable, differentiating between comparisons that employed two all-male participant groups, two mixed participant groups with gender matching, or

Table 9
Gender as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Gender		(2, 124)	3.10	0.0488*				
All male	65				−0.40	45.8	−1.24	0.2198
Mixed	112				0.15	33.2	0.62	0.5425
Not matched	59				−0.63	105.0	−1.76	0.0814

Note. Data displayed include both accuracy and reaction time data; Not matched = both participant groups differ in gender; All male = both participant groups are all-male; Mixed = both participant groups have a mixed gender group; ES = effect sizes; *g* refers to Hedges' *g* effect size.
* $p < .05$.

Table 10
Age as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
Age		(4, 170)	3.17	.0153*				
6y–12y	74				0.22	70.1	0.79	.4347
12y–18y	77				−0.11	68.5	−0.38	.7031
18y–35y	59				−0.34	63.0	−1.16	.2505
y(ASD) < y(TD)	21				−0.90	184.0	−2.57	.0109*
y(ASD) > y(TD)	44				0.17	108.0	0.58	.5648

Note. Data displayed include both accuracy and reaction time data; y = age in years; ES = effect sizes; *g* = Hedges' *g* effect size.
* $p < .05$.

two nonmatched participant groups. Given only four observed effect sizes were available on all-female groups, this category was excluded from the analysis. Although the estimated group difference significantly varied for these three categories, for none of the categories a significant group difference was actually obtained (see Table 9), $F(2, 124) = 3.10$, $p = .0488$.

Age. Examining the impact of the mean age of the entire participant group as a continuous variable revealed no significant effect (range = 8.0–30.0, $M = 15.61$, $SD = 5.97$; $F(1, 121) = 2.18$, $p = .1423$). Although not significant, there was a trend suggesting worse performance for the ASD group with increasing overall mean age. This trend became stronger when only taking into account the age of the typically developing group (range = 6.5–30.0, $M = 15.26$, $SD = 6.23$; $F(1, 193) = 9.13$, $p = .0029$), but disappeared when merely taking into account the age of the ASD group (range = 8–34.6, $M = 16.06$, $SD = 6.71$; $F(1, 184) = 0.10$, $p = .7535$). In order to clarify the influence of age on group differences, age was included as a categorical variable. Comparisons of participant groups matched for age, that is, children between 6- and 12-years old, adolescents between 12- and 18-years-old and adults between 18- and 35-years-old, did not yield group differences. However, comparing performances for unmatched groups revealed a significantly worse performance for ASD participants when a younger ASD group was compared with an older typically developing group (see Table 10; $g = -.90$, $t(184) = -2.57$, $p = .01$). Although such an effect seems intuitive, it is important to add that this effect was not present in the opposite direction, namely comparing an older ASD group with a younger typically developing group. This finding suggests a more subtle developmental difference between ASD and typically developing groups, that is, a difference in the pace of the developmental course.

Intellectual ability. With regard to intellectual ability, analyses were conducted in terms of FSIQ as well as NVIQ. Looking at the influence of FSIQ on group performance revealed no significant difference (see Table 11), $F(4, 30.5) = 1.09$, $p = .3791$. A similar lack of group differences was obtained for effect sizes where both participant groups were matched for FSIQ (i.e., 40 < IQ ≤ 70, 70 < IQ ≤ 100, 100 < IQ ≤ 120), as for comparisons where participant groups were not matched for FSIQ. Evaluating the influence of NVIQ only, as in ASD verbal abilities are known to be affected more than nonverbal abilities, revealed similar results as with FSIQ, $F(4, 23.6) = 0.80$, $p = .7535$. No group differences were found, neither for the NVIQ-matched comparisons nor for the nonmatched comparisons (see Table 12).

Discussion

This article used formal meta-analysis to examine whether individuals with autism spectrum disorder differ in perceptual organization compared to typically developing individuals. We examined 56 studies, testing about 1,000 ASD participants. We provided evidence that differences in perceptual organization in ASD are limited to the speed with which global order is processed. Individuals with ASD are slower in global-order perception than typically developing individuals, in particular when having to attend to global order while incongruent information is present at the local level. This suggests local-to-global interference in individuals with ASD, rather than global-to-local interference as is often discussed in typically

Table 11
FSIQ as a Moderator Variable

	Number of observed ES	*df*	*F*	*p* > *F*	*g*	*df*	*t*	*p* > *t*
FSIQ		(4, 30.5)	1.09	.3791				
40 < FSIQ ≤ 70	38				1.47	23.9	1.73	.0965
70 < FSIQ ≤ 100	37				−0.37	27.7	−0.75	.4576
100 < FSIQ ≤ 120	101				−0.35	32.6	−1.13	.2679
FSIQ(ASD) < FSIQ(TD)	20				−0.33	42.4	−0.49	.6281
FSIQ(ASD) > FSIQ(TD)	9				0.20	28.6	0.18	.8588

Note. Data displayed include both accuracy and reaction time data; FSIQ = Full Scale Intelligent Quotient; ES = effect sizes; *g* refers to Hedges' *g* effect size.

Table 12
NVIQ as a Moderator Variable

	Number of observed ES	*df*	*F*	$p > F$	*g*	*df*	*t*	$p > t$
NVIQ		(4, 23.6)	0.80	.5380				
$40 < \text{NVIQ} \leq 70$	38				1.48	18.3	1.54	.1405
$70 < \text{NVIQ} \leq 100$	25				−0.44	21.7	−0.72	.4796
$100 < \text{NVIQ} \leq 120$	77				−0.22	24.6	−0.51	.6120
NVIQ(ASD) < NVIQ(TD)	20				−0.28	32.7	−0.37	.7127
NVIQ(ASD) > NVIQ(TD)	9				0.20	21.7	0.16	.8719

Note. Data displayed include both accuracy and reaction time data; NVIQ = Nonverbal Intelligent Quotient; ES = effect sizes; *g* refers to Hedges' *g* effect size.

developing individuals (Navon, 1977, 1981). Individuals with ASD do not display a general deficit in perception of global order, as they do not differ in terms of accuracy but are merely slower at grasping the *gist*. The type of performance measure (accuracy vs. RT) and the level(s) of visual processing (local information, global information, or both) both affect performance and mediate the group differences. The type of task administered, as well as the age, gender, and FSIQ of either participant group do not determine any overall group differences, but small task-dependent group differences.

Temporal Aspects of Perceiving Local and/or Global Order

We conclude that individuals with and without ASD differ in the speed with which they perceive global order: Individuals with ASD take longer to perceive global order than individuals without ASD, in particular when incongruent local information is present. As this conclusion challenges some generally accepted ideas in the field, we discuss our findings with respect to several major frameworks in ASD vision research as well as vision research in typically developing.

A first theory to consider is the WCC theory, which postulates that individuals with ASD have difficulties integrating information into a meaningful whole, while their local order processing is enhanced or at least preserved (Frith & Happé, 1994; Happé & Booth, 2008; Happé & Frith, 2006). Although our findings do not support *overall* weak central coherence or a global processing deficit, they do indicate more time-consuming global processing and preserved local visual processing for individuals with ASD. The evidence presented here is in line with the idea of (partial) independency of one's ability to process local or global factors, as suggested by Happé and Booth (2008). If the ability to process local or global elements were to constitute two extremes of one continuum, one would expect diminished global processing to go hand-in-hand with preserved local processing, or diminished local processing to go hand-in-hand with global processing. Neither of these patterns of performance, however, were obtained in our meta-analysis.

A second framework to consider is the EPF hypothesis, which suggests that individuals with ASD show enhanced (low-level) local processing and adequate, though less automatic, global processing (Mottron et al., 2013; Mottron & Burack, 2001; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006). No supporting evidence was obtained for EPF's claim of enhanced local processing, not in terms of accuracy, nor for speed of processing. Note, however, that no distinction was made between low- and high-level stimuli, as this proved problematic to encode. In terms of global visual processing, EPF suggests less mandatory, more optional global processing in ASD, which is in line with the evidence of time-consuming global-order perception as revealed in our analysis.

In typically developing individuals a relative precedence of the global configuration has been suggested for years. In many cases the individuation of elements only occurs later, while grouping into global configurations would happen rapidly and effortlessly (Kimchi, 1992).

The Reverse-Hierarchy Theory, developed by Hochstein and Ahissar (2002; Ahissar & Hochstein, 2004) postulates early access to gist-level information and late access to details in typical adults, with high-level perception dominating initial perception and perception of details emerging only after focusing of attention (Ahissar & Hochstein, 2004; Hochstein & Ahissar, 2002). The theory dissociates between early explicit perception ("vision at glance") and implicit low-level vision ("vision with scrutiny"), explaining a variety of phenomena. This idea of rapid global-to-local progression of perceptual information was later on, amongst others, supported by Sweeny, Grabowecky, and Suzuki (2011), who demonstrated that the global spatial arrangement of a group of shapes influenced immediate local perception (SOA = 40 ms), but not later local perception (SOA = 140 ms). Our findings on perceptual organization suggest different mechanisms to play a role in ASD than in typically developing, as in ASD grouping into global configurations only seemed to occur with time and seemed to require explicit effort, especially when incongruent low-level information was present. This suggests that in ASD early explicit perception is less about gist-level information and more about access to details, or a local-to-global progression of perceptual information processing.

Based on this meta-analysis, we believe future perceptual research in ASD would benefit from focusing more on the temporal aspects of the local–global visual *process*, rather than the current ability-or-inability approach that concentrates on the outcome of perceptual organization. We propose to focus on the interplay of local- and global-order, examining the precise nature of the default processing mode, as well as the relative speed of specific types of visual processing in the absence or presence of another.

Perceptual Organization Across Tasks

Many different tasks and paradigms have been designed to examine local–global visual processing in typically developing as well as in patient populations. Although one might expect rather similar results from tasks that are designed to measure the same construct, our meta-analysis revealed different (group) effects depending on the task being administered.

For hierarchical figures and letters, an interesting double interference-effect was found: When individuals with ASD process a two-layered, hierarchical stimulus they are slower when having to attend to the global configuration and ignore the (in)congruent local-level input, and more accurate than typically developing when having to attend to the local configuration and ignore the global-level input. Although many caveats have been raised with respect to the hierarchical letters and figures (Kimchi, 1992), the fact that within one task, an accuracy and RT measure of both local and global processing (with or without interference elements) are generated, is highly valuable, as it limits the effects specific task characteristic might have (cf. supra).

For visual search tasks, a rather unexpected group difference was found, as individuals with ASD proved not to be faster than typically developing individuals. One way to understand the lack of group difference is that both in a feature and (even more so) in a conjunction search, "pop-out" only occurs once the visual system has determined what the majority of features in a visual scene are like. Recent work on ensemble encoding has suggested that access to gist representations constitutes the front-end stage of (visual) search (Haberman & Whitney, 2012). Given quick gist perception is beneficial in search, our findings of delayed gist perception in ASD might be a possible factor in understanding search for ASD.

For block design, embedded figures, discrimination, visual illusions, or drawing, no reliable overall group differences were found, neither for local visual processing, nor for global processing. These results contradict the general consensus, especially the results on block design and embedded figures, as both of these paradigms were used in the pioneering studies on atypical local–global processing (Shah & Frith, 1983, 1993) and are often referred to as *standard* tasks to mark atypical visual processing in ASD.

However, these task-related findings are not only informative with regard to visual perception in ASD. In line with Milne and Szczerbinski's (2009) factor analysis, these findings strongly indicate that the tasks typically used to study local and global visual processing are not measuring the same concepts or constructs, and are not evaluating visual processing in the same way. This is important to note, as these task are often used as if they are truly interchangeable. A reevaluation of these tasks and, in particular, their underlying constructs is therefore necessary. We propose several alterations to task construction and visual processing research in ASD in general, in order to enable further progress (see Future Directions).

Developmental Trajectories

In ASD research, many speculations have been formulated on the importance of gender, age, or intellectual ability in order to uncover group differences between ASD individuals and typically developing individuals. Here, we have shown that no notable group differences are found on local–global visual processing tasks depending on whether the groups are matched for gender or not. Note that comparisons consisting of all-female groups only were excluded from the analysis, and therefore, no claims can be made with regard to differences between all-female and all-male or mixed participant groups. Whereas the percentage of females in the ASD participant group did not impact overall group differences, an increasing percentage of females in the TD participant group was significantly linked to a better performance in the ASD group. One underlying reason for this might be that, in typically developing individuals, it has often been suggested that overall, males tend to perform better on tasks associated with the right hemisphere (e.g., visuospatial tasks), while girls perform better on tasks associated with the left hemisphere (e.g., verbal tasks; e.g., Kramer, Ellenberg, Leonard, & Share, 1996). That the percentage of females only yields an effect when taking into the TD participant group and not the ASD participant group, might be due to the fact that the TD group has more variation in the percentage of females included than the ASD group (TD: $M = 16\%$, $SD = 13\%$; ASD: $M = 11\%$, $SD = 14\%$). With regard to age and intellectual ability, we have found no significant differences for matched groups. Comparing two unmatched age groups, analyses revealed a particular asymmetry: worse performance for younger or ASD participants compared with older TD participants but no difference when comparing older ASD participants with younger TD participants. These findings suggest a subtle difference in the pace of the developmental trajectory of ASD participants.

Overall, our results on age, gender, and intellectual ability suggest that difficulties with perceptual organization are not specific to any particular subgroup of ASD individuals, such as low-functioning individuals or young children. Although there is considerable debate about the developmental trajectory of local–global visual processing, this finding might be somewhat surprising (e.g., Poirel et al., 2011; Scherf, Behrmann, Kimchi, & Luna, 2009). It is important to note, however, that low-functioning individuals, toddlers and preschoolers, as well as females, remain outnumbered by other subgroups within autism research, which constrains the conclusion on can draw from this. Although the fact that comparing unmatched age groups comes with a cost for the ASD group but not for the typically developing group points in the direction of a subtle developmental difference, further (longitudinal) research with these specific subgroups seems necessary in order to allow stronger claims to be made. As many studies included in this meta-analysis provided only limited information on their participant groups, it proved difficult to delineate more narrow age- or IQ groups. For now, it remains difficult to formulate strong conclusions regarding the developmental trajectory that distinguishes ASD individuals from typically developing individuals or the possibility that compensational mechanisms evolve through childhood.

Methodological Issues

A meta-analysis is fundamentally limited by the quality and quantity of its input data. Although this is inherent to every meta-analysis, this brings about some specific methodological issues. A first point concerns the *file-drawer problem* (Rosenthal, 1979), which refers to a possible bias in meta-analytic results due to the fact that studies with significant results are more eagerly accepted by publishers than nonsignificant (null) findings. As research on perceptual organization in ASD is still fully ongoing and known to suffer from contradictory research results, we would like to argue that all data, including both significant and nonsignificant results, would be considered valuable and accepted for publication to an equal extent. Therefore, we expected a possible file-drawer problem or general publication bias to be limited in size. However, as revealed by the funnel plot (Egger et al., 1997), Begg and Mazumdar (1994) rank correlation test and Duval and Tweedie's (2000) trim and fill method, concerns on publication bias should not be discarded. Under the random effect model the Trim and Fill method suggested 50 observed effect sizes to be missing on the left side (negative findings) and no effect sizes to be missing on the right side (positive findings). This means that the population effect is probably even larger than the effect estimated based on the effect sizes found in the literature, that is, performance of the ASD group is suggested to be worse than estimated based on the effect sizes, upon comparison with the typically developing group. A third methodological issue concerns the large heterogeneity and diversity in what studies on visual processing in ASD report and therefore, what we were able to code in the analysis. Several studies were (partly) excluded from the analysis as a result of not reporting the necessary descriptive statistics or test statistics in detail (e.g., merely plotting data and not reporting actual numbers). In addition, with only 44 out of 56 included studies reporting age, FSIQ, and gender, examination of their moderating effect was hampered, as the array of categories is swayed and the statistical power reduced. Most scholars report information at the group level (e.g., gender ratio) and do not report data on subgroups separately. Such incomplete reporting affects the interpretability of the results and, in a later stage, the sample of a meta-analysis. As a result, one can no longer assess individual differences, nor all moderating variables. To ensure validity of our analyses and the conclusions here drawn, we have not reported moderating factors for which less than 75% of all data was present (e.g., implicit or explicit task instruction, low- or high-level stimuli, type of autism spectrum disorder, etc.).

Future Directions

To our knowledge, this study is the first meta-analysis on local and global visual processing in ASD. We have assembled and combined the 30 years' worth of data that has been published in English journal articles. Based on our analysis of the literature, we suggest several ways to improve future research on local and global visual processing.

First of all, we argue that this research field would benefit from an improved operationalization of both "local" and "global" processing. Although we do not argue for one golden-standard operationalization, we do believe transparency and a more explicit argumentation form the master key to progress and improvement. Measured in a wide variety of tasks and with a broad range of possible manipulations, the hazard lies in the fact that several important aspects of the operationalization are often not discussed by the researchers. Although the tasks and paradigms applied may not be invalid operationalizations per se, the validity and quality of the operationalization depends on what one specifically tries to operationalize. A first problem entails which level(s) of visual processing scholars aim to tap into when administering a certain task or paradigm. Method sections discuss the applied stimuli or paradigms rather than to what extent and how local and global processing were operationalized and to what extent this particular emphasis on one or the other component was desired. For instance, is local-to-global or global-to-local interference of interest, or should the possibility of an interference effect be avoided? Consistent with Milne and Szczerbinski (2009), this meta-analytic review has revealed that different tasks yield different response patterns and distinctions based on the aim of the task (in terms of level(s) of visual processing) are far superior over distinctions made based on the applied stimuli or paradigms. We believe that, if scholars were more explicit in their argumentation for a particular combination of task and stimuli, given their particular aim, this would allow for better peer review of the operationalization and more correct interpretation as well as generalization. A second problem along this line is the fact that most researchers do not seem to consider the impact of task-irrelevant visual information present, nor the effect that can result from differences in the relative strength of the local and global levels of processing. However, as both of these elements can prove crucial in terms of the resulting performance and the interpretation of the results, we believe these should be manipulated with sufficient deliberation. One way of investigating the effect of additional, task-(ir)relevant information, or multilayered information in general, is by comparing performance for congruent Navon stimuli with performance for incongruent Navon stimuli. To examine the impact of the relative strength of the local and global levels of processing, one could compare performance for embedded figures tasks with well-known images at the global level (e.g., car or house), to performance for an embedded figures tasks with random, meaningless shapes at the global level. Although in both types of embedded figures a global level is present, the relative strength of each global level and its interference on the local level, differ. Based on the conclusions of our meta-analysis, we would predict performance of ASD individuals to benefit less from strong global levels than typically developing individuals, when comparing performance on strong global levels with weak global levels in a EFT task. One attempt along this line has been made by de-Wit, Degroef, Van der Hallen, and Wagemans (2013), who have constructed an embedded figures test that systematically manipulates the perceptual factors that contribute to the embedding of a target. They manipulated the presence of task-(ir)relevant information as well as the relative strength of embedding, through manipulation of the number lines, number of line continuations and number of line crossings for each target and each embedding context. A third and last component of this problem concerns the explicit versus implicit nature of the given task instruction. Research has shown how a specific task instruction can impact visual processing in ASD (Koldewyn et al., 2013). Unfortunately, we were unable to include this as moderator variable in our analysis due to a lack of articles providing the necessary information. Given the fact that the nature of the task instruction can influence performance and this is not reported currently, we advocate for researchers to acknowledge this impact, to make well-thought-out decisions and to discuss these carefully in their articles.

A second major area of improvement for the field of local–global visual processing involves the theoretical position of researchers on the "local" and "global" constructs. Although several interesting issues have been discussed in more theoretical articles (Happé & Booth, 2008; Koldewyn et al., 2013; Milne & Szczerbinski, 2009), the influence of these on experimental research publications seems rather limited so far. Nevertheless, how one conceptualizes local–global visual processing, how one regards a task or paradigm as operationalizing one kind of processing or another, and how one interprets research findings, all depend on one's theoretical framework. For instance, does the embedded figures task reveal enhanced local processing abilities, the lack of global processing abilities, or a disturbed balance between local and global processing? Scholars' ideas on the concepts and constructs of local and global visual processing are now, all too often, insufficiently spelled out. We believe that, in addition to explicit argumentation and enhanced transparency, such clear discussions of one's theoretical standpoint on the applied concepts and constructs, would highly benefit the local–global research and could considered crucial in ensuring this field a scientific future. Recent research on atypical visual processing in ASD is moving away from all-or-nothing notions such as "disability," "impairment," or "deficits" and has started thinking more in lines of differences in "preference," "liking," or "habitual behavior" (e.g., Koldewyn et al., 2013). This shift in terminology does not represent merely a lexical choice, but represents a shift in evidence for more subtle differences rather than all-or-nothing deficits, in line with our meta-analytic results.

Summary

With this meta-analysis, we provide evidence that differences in perceptual organization in ASD are limited to the speed with which global order is processed. Individuals with ASD are slower in global-order perception than typically developing individuals, in particular when having to attend to global order while incongruent information is present at the local level. This suggests local-to-global interference in individuals with ASD, rather than global-to-local interference as is often discussed in typically developing individuals (Navon, 1977, 1981). We find no overall deficit or impairment in perceptual organization, but a difference in the temporal interplay between local and global levels of processing visual information, with local processing being the more spontaneous, automatic style of processing for individuals with ASD, even in situations (stimuli or tasks) where typically developing individuals employ a more global processing style.

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