1. Is children's naming and drawing of pictures mediated by representational intentions? Evidence from typical development and autism.

Pictures are symbols for entities that exist independently in time and space. Because they are intended to symbolise real objects, it is the cultural norm to assign object names to 2-dimensional representations (i.e. real monkeys and monkey pictures can be referred to with the word "monkey"). Previous research has debated over the cues that direct picture naming in typically developing (TD) children. One possibility is that children simply label shape, without reflecting on factors that are external to the perceptible image (i.e. if an image is shaped like a cat, it is "a cat"; Browne & Woolley, 2001; Freeman, 1991; Freeman & Sanger, 1995). Alternatively, children might label pictures according to artists' referential *intentions* (i.e. a picture is "a cat" only if it was created with the intention of representing a cat; Bloom & Markson, 1998; Gelman & Ebeling, 1998; Hartley & Allen, 2014). Our research has two primary aims: we investigate the influence of intention reading on picture interpretation in TD children aged 2-5 years, and also examine how children with intention monitoring difficulties derive meaning from pictures. Children with Autism Spectrum Disorder (ASD) have great difficulty understanding the mental states of others (Allen, 2009; Baron-Cohen, Baldwin & Crowson, 1997; Charman et al.,1997; Griffin, 2002; Hartley & Allen, 2014; Hobson, 2002), therefore studying this population can provide additional evidence for the role of intention reading in typical pictorial understanding *and* highlight potential differences in their processing.

Several studies have investigated whether TD children reflect on referential intentions when naming pictures. Browne and Woolley (2001) showed 4- to 7-year-old TD children and adults a puppet show in which the protagonist announced his intention to draw a bear, but actually produced a picture that resembled a rabbit. Subsequently, the majority of each age group named the picture according to its shape (e.g. a rabbit) rather than the artist's stated intention (e.g. a bear). This finding suggests that, when viewing images that are sufficiently recognisable, TD children assign labels based on shape rather than intentions. However, by employing pictures that unambiguously resemble familiar nameable objects other than their intended referents, children are presented with an unusual and confusing test situation. As it is extremely irregular to encounter a drawing that is intended to represent X, but uniquely resembles Y, participants in these circumstances may disregard the artist's intentions in an attempt to reconcile the conflicting cues. While it is unlikely that an artist would draw one object whilst intending to represent something else, it is culturally acceptable to assign meaning to *ambiguous* images (e.g. abstract art, infant scribbles). Indeed, examining how children interpret ambiguous pictures can provide a more ecologically valid method of assessing the relative importance of resemblance and representational intent to children's picture naming (Hartley & Allen, 2014).

In their often-cited study, Bloom and Markson (1998) asked TD 3- and 4-year-olds to draw pairs of objects that closely resembled each other, such as a balloon and a lollipop. Predictably, the pairs of pictures produced by the young children were virtually indistinguishable, and thus could not be accurately matched to their original referents based on shape alone. Nevertheless, when asked to name their drawings after a distracter task, both age groups correctly and consistently discriminated based on their original representational intentions. Bloom and Markson (1998) propose that "children might call a picture that looks like a bird "a bird" not merely because it looks like a bird, but because its appearance makes it likely that it was created with the intent to represent a bird" (p. 203). In other words, TD children might name shape only insofar as it provides an index of representation. Gelman and Ebeling (1998) tested this theory by directly measuring whether children's naming of 2-D shapes is mediated by whether they are *intended* to be representational. In their study, TD 2- and 3-year-olds were shown a series of line drawings roughly shaped like familiar nameable objects (e.g. a kite). Some children were informed that the pictures had been created intentionally (e.g. someone painted a picture), while others were told that the pictures had been created by accident (e.g. someone spilled some paint). When asked to label the pictures, children were more likely to name according to shape when they believed that the images were intentional creations, and provided more literal non-symbolic responses (e.g. naming materials such as “paint”) when they were made accidentally. Thus, the tendency of TD children to name a picture’s shape may be influenced by representational status, which is ultimately determined by the intentions of its creator.

To advance theoretical understanding of how intentions mediate picture comprehension in typical development, it is necessary to utilise complementary methodologies that tap into conceptual representation over-and-above verbal labelling (Karmiloff-Smith, 1990). If a TD child believes an ambiguous collection of lines was created with the intention of representing a familiar object, asking them to draw that stimuli may lead to the depiction of additional details that correspond with the symbolised referent. Increasing the level of picture-referent resemblance could be taken as further confirmation that the child genuinely regards the image to be a symbol, despite the relatively low degree of iconicity. Conversely, if a different child believes that the same collection of lines was created by accident, and infers it to be non-representational, their graphic reproduction might be more faithful to the perceived stimuli.

Potentially independent of an intentionality effect, children’s graphic copies of ambiguous shapes might be influenced by their own verbal labelling. Previous research investigating TD children’s drawing of objects has shown that they selectively represent different details depending on its designated label (Krascum, Tregenza & Whitehead, 1996; Lewis, Russel & Berridge, 1993; Pickard & Vinter, 1999). For example, Lewis, Russell and Berridge (1993) asked 5-year-olds to draw a tankard from an unusual perspective (its handle was occluded), after it was called “a mug”, “a glass” or “this”. They found that children depicted the occluded handle in 69% of “mug” trials, 48% of “this” trials and 27% of “glass” trials. It was likely that the labels “mug” and “glass” directed children’s attention away from the perceived stimuli, and towards conceptual knowledge about the object referents of the labels (Toomela, 2002). As TD children are highly aware of others as attentional and intentional agents (e.g. Carpenter, Akhtar, & Tomasello, 1998; Gergely, Nadasdy, Csibra, & Biro, 1995), they might be more likely to name and canonically represent ambiguous figures that they judge to be intentional, rather than accidental, creations. However, it is possible that children who assign object names to accidentally created figures may also produce increasingly canonical graphic copies, suggesting that egocentric verbal labelling can influence children’s drawings in the absence of inferred communicative intentions.

If intention reading is an important component of children’s picture comprehension, we might expect to observe important differences in children with ASD. ASD is a pervasive neurodevelopmental disorder that is characterised by profound social-cognitive deficits (Baron-Cohen, 1995; DSM-IV: American Psychiatric Association, 1994; Frith, 2003; Kanner, 1943). Many children with ASD have great difficulty understanding the mental states of others, including their intentions (Baron-Cohen, 1995; Charman et al., 1997; Griffin, 2002; Hobson, 2002; Mundy & Willoughby, 1996). Deficits in intention reading permeate numerous aspects of autistic development, including children’s understanding of goal-directed actions (D’Entremont & Yazbek, 2007; Hartley & Allen, 2014), word-referent mapping (Baron-Cohen et al., 1997; Preissler & Carey, 2005) and picture-object mapping (Allen, 2009; Hartley & Allen, 2014). For example, in their recent paper, Hartley and Allen (2014) reported that minimally-verbal children with ASD do not reflect on artists’ intentions when mapping pictures to objects. While TD toddlers related abstract pictures to intended referents they did not resemble, children with ASD mapped the same pictures to *non-intended* referents they happened to resemble. However, it is not yet known whether functionally verbal children with ASD consider representational intentions when *naming* pictures created by others. Furthermore, if children with ASD do not intuitively reflect on pictures as creations of other humans with psychological relations to the world (Hartley & Allen, 2014), the appearance of their graphic copies may not be related to whether figures are intentional or accidental creations. Rather, their drawings may be influenced more by their own verbal labelling, perhaps indicating an egocentric style of picture comprehension.

The objective of this study was to examine the influence of representational intentions on children's picture comprehension. This was achieved by comparing two age groups of TD children (2- to 3-year-olds and 4- to 5-year-olds) and a sample of children with ASD. It is well-documented that children with ASD have difficulty understanding the intentions of others, and differences in their pattern of performance may serve to reinforce the role of intention reading abilities in normative pictorial understanding. The younger TD age group was selected based on the success of 2- and 3-year-olds in Gelman and Ebeling (1998), and the older group (4- to 5-year-olds) was included to capture age-related changes in productive and representational drawing abilities which surface between 3- and 5-years (Cox, 2005; Jolley, Knox, & Foster, 2000; Luquet, 2001; Toomela, 1999). It is also possible that the continued refinement of intention reading skills during this developmental period (see Jenkins & Astington, 1996; Phillips, Baron-Cohen, & Rutter, 1998; Wellman & Phillips, 2001) may impact on how referential intent directs naming and drawing, making it important to directly compare the responses of younger and older TD children.

All participants were shown a series of line drawings roughly shaped like familiar nameable objects. Half the children in each group were informed that the pictures had been created intentionally, and half were informed that the pictures had been created accidentally. At test, children were asked to name the pictures, and then to draw them. Children's drawings were coded based on the degree to which they resembled the symbolised intended referent or the perceived stimulus. As in Gelman and Ebeling (1998), we predicted that the shape-based naming of both TD groups would be influenced by whether the ambiguous figures were created intentionally, and thus inferred to be symbolic. Hence, we expected a high rate of shape naming responses in the Intentional Condition, and a reduced rate of shape naming responses (balanced by an increase in non-symbolic material responses, such as "paint") in the Accidental Condition. We expected that the graphic reproductions of TD children could be influenced by 3 factors: chronological age, representational intentions, and children's prior naming. Independent of other factors, we expected to observe an increase in the frequency of faithful drawings with age, as children begin to draw in an increasingly realistic manner (Luquet, 2001; Cox, 1992, 2005; Golomb, 2002, 2004; Jolley, 2010). Regarding representational intentions, we expected that intentionally-created stimuli would elicit an increase in the proportion of canonical representations of symbolised referents, while non-symbolic accidentally-created stimuli would elicit a relative increase in faithful reproductions. Lastly, we expected that children's naming of shape could induce the creation of more canonical reproductions of stimuli, independent of representational intentions (e.g. they may produce canonical drawings of accidental stimuli if they named its shape).

For children with ASD, we predicted that children's symbolic naming and graphic copying of ambiguous shapes would not be mediated by artists' representational intentions. Also, while their copying might not be influenced by artists' intentions, it could be related to their own egocentric labelling. If so, they should be more likely to produce canonical representations after providing symbolic shape-based labels, and faithful representations after providing non-symbolic material labels. Overall, this study will advance understanding of the relation between intention reading and picture comprehension by assessing whether 2- to 5-

year-old TD children are sensitive to artists' intentions when naming and copying ambiguous figures, and by providing converging evidence that children with ASD are not.

2. Method

2.1 Participants

Participants were 32 TD 2- and 3-year-olds (17 males, 15 females; *M* age = 3;1, range: 2;1–3;11, *SD* = 0;7), 32 TD 4- and 5-year-olds (16 males, 16 females; *M* age = 4;11, range = 4;0–5;9, *SD* = 0;6), and 20 children with ASD (19 males, 1 female; *M* age = 9;8, range = 4;11–16;2, *SD* = 3;5) recruited from mainstream schools, specialist schools, nurseries and preschools in Kendal and Preston, UK. Children with ASD were diagnosed by a qualified educational or clinical psychologist, using standardised instruments (i.e. Autism Diagnostic Observation Scale and Autism Diagnostic Interview - Revised; Lord, Rutter, DiLavore & Risi, 2002; Lord, Rutter & Le Couteur, 1994) and expert judgment. ASD diagnoses were confirmed via the Childhood Autism Rating Scale (CARS; Schopler, Reichler, DeVellis & Daly, 1980), which was completed by each participant's class teacher (*M* score: 38.75, range: 31.5–51.5). Each participant's receptive vocabulary was measured by the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton & Burley, 1997), an instrument that is commonly used to assess children aged 3-years and older.[1] Mean receptive vocabulary age-equivalent scores for the 3 groups were as follows: 3;7 for TD 2- and 3-year-olds (range: 2;0–5;10, *SD* = 0;11), 5;6 for TD 4- and 5-year-olds (range: 3;1–8;2, *SD* = 1;3), and 4;3 for children with ASD (range: 2;0–6;5, *SD* = 1;2). A one-way ANOVA revealed significant group differences in receptive language ability, $F(2, 81) = 26.47$, $MSE = 176.49$, $p < .001$, $\eta^2 = .65$; the 4- and 5-year-olds had greater ability than the other two groups ($p < .001$), and there was a borderline difference for greater ability in the ASD group relative to the TD 2-

[1] The BPVS score of one child with autism was marginally below the lowest raw score with a standardised age equivalent (of 2;3). Consequently, we conservatively assigned this child a receptive language ability of exactly 2;0.

and 3-year-olds (*p* = .067). In order to assess the effect of ASD on the relation between children's verbal and drawing responses, children with ASD were group matched to a subset of TD participants on receptive language ability (see analyses of drawing responses). All children with ASD were functionally verbal, and thus able to name pictures as required.

Half of the children in each group were randomly assigned to the Intentional Condition and half to the Accidental Condition. TD 2- and 3-year-olds in the two conditions did not differ on chronological age or receptive language. This was also true for the TD 4- and 5-year-olds. Children with ASD in the two conditions did not differ on chronological age, receptive language or CARS score.

2.2 Materials

The stimuli were four black-and-white pictures (see Fig. 1) selected from Gelman and Ebeling's (1998) Study 2. As children were required to draw each picture, we reasoned that more than 4 items would be too demanding for participants in a single session. The drawings were scanned from the original article and made approximately 4 times larger. The digital stimuli were printed by a high-quality laser printer and laminated. Each drawing had two accompanying stories – one per condition. These were identical to those used in the original study, except for a small number of cultural adjustments (e.g. replacing 'art class' with 'art lesson'). In one story, it was suggested that the picture had been created intentionally. In the other story, it was suggested that the same picture had been created accidentally. As in the original study, the target picture was said to have been created using the same material in both stories. See Appendix A for a full listing of the stories.

The participants drew the pictures using a selection of coloured felt-tip pens and crayons on white A4 paper.

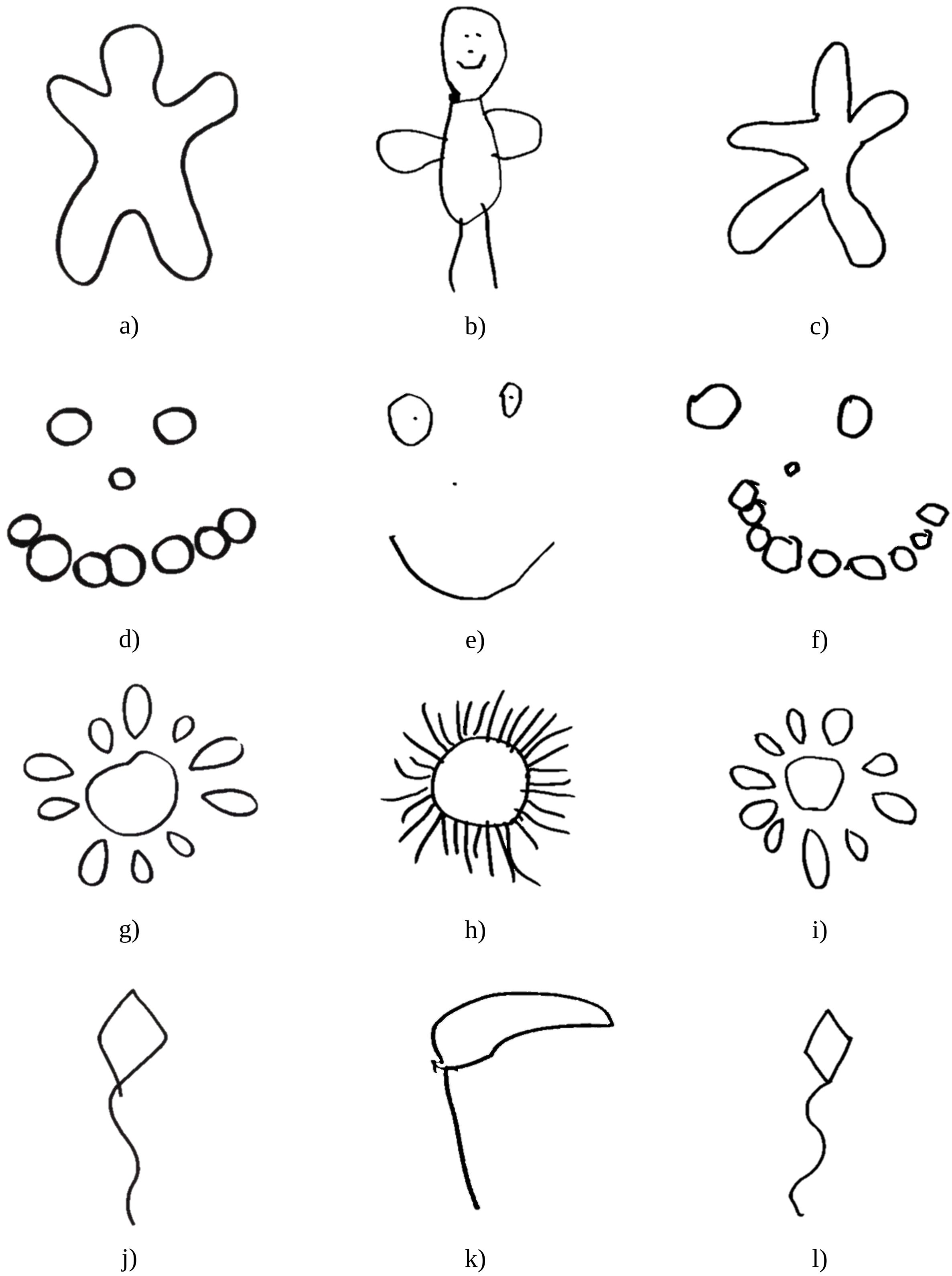

Figure 1. Stimuli and sample drawing responses; a) stimuli “man”, b) representational man, c) faithful man, d) stimuli “face”, e) representational face, f) faithful face, g) stimuli “sun”, h) representational sun, i) faithful sun, j) stimuli “kite”, k) representational kite, l) faithful kite.

2.3 Procedure

Participants were tested individually in their own schools and were always accompanied by a familiar adult. They were seated at a table next to or opposite the experimenter and the materials were placed within their reach. Children were reinforced throughout the session for attention and good behaviour, but the experimenter never indicated whether their responses were correct or incorrect.

Children received either the Intentional Condition or the Accidental Condition. Both conditions consisted of 4 trials. At the start of each trial, the experimenter read aloud a brief story explaining how a fictional character had created a picture intentionally or accidentally (dependent on condition). The corresponding picture was then presented and the experimenter asked, "what is this?" If the participant responded with "I don't know", one additional prompt was provided. After their response had been recorded, the experimenter presented the participant with a sheet of white A4 paper and a packet of colouring pens and asked, "can you draw this?" Once the participant had finished drawing, the paper was removed from sight by the experimenter. The order in which the four items were presented was counterbalanced between participants.

2.4 Coding

2.4.1 Verbal responses. Following Gelman and Ebeling's (1998) scheme, the verbal responses of children were coded as belonging to one of four mutually-exclusive categories:

a) 'Shape' – the child named an object that was not mentioned in the experimenter's story, and that corresponded to the shape of the picture (e.g. "a gingerbread man", "a kite", "a face", "a sun"). This response indicated that the child regarded the picture as a symbol.

b) 'Material' – the child named the material that the picture had supposedly been made from (e.g. "paint", "mud", "string") or referred to it in non-symbolic terms (e.g. "a splat"). This response indicated that the child did not regard the picture as a symbol.

c) ‘Do Not Know’ – the child indicated that they did not know what the picture was, or simply did not respond.

d) ‘Other’ – the child mentioned physical resemblance (e.g. “it looks like a x”) or provided the name of an object/material that was not mentioned in the experimenter’s story nor corresponded to the shape of the picture (e.g. “kangaroo”).

2.4.2 Drawing responses. After labelling each ambiguous figure, children were asked to create their own graphic copy. Coding schemes were created that enabled raters to categorise children’s reproductions of each figure as either Representational (drawing more closely resembled the symbolised referent than the stimuli), Faithful (drawing more closely resembled the stimuli than the symbolised referent) or Uncodable (drawing resembled neither the stimuli nor the symbolised referent). The coding schemes included a list of key features, and coders judged according to criteria whether or not a child’s drawing reproduced each feature in either a faithful or canonical fashion. This coding method yielded two scores per drawing (each out of 5) reflecting how Representational/Faithful it was. Drawings were *categorised* based on which score – Representational or Faithful – was higher (i.e. if more features were represented canonically than faithfully, a drawing was categorised as Representational; see Fig. 1 for example drawings). Not all features were weighted equally – for each ambiguous figure a key detail was identified that served as a clear indicator of whether a child’s drawing was a Representational or Faithful reproduction (e.g. drawing the “mouth” of the face-like picture as a horizontal line curving upwards at both ends, as children tend to represent smiles, versus drawing a row of individual circular shapes as displayed in the stimuli), and this feature was allocated more Representational/Faithful points. An example coding scheme (for the ambiguous figure resembling ‘a man’) is described below (all coding schemes are documented in Appendix B).

Example coding scheme - Man

1. ‘Uncodable’ – drawing does not share perceptual similarity with either stimuli or symbolised referent (e.g. drawing is a scribble or series of randomly-placed disconnected shapes). If the drawing does not fulfil criteria for Uncodable classification, proceed with coding.

If not Uncodable:

2. ‘Head’

a) Enclosed circular shape located at the top of the drawing. May be attached to a central shape or a vertical line. Score: 1 Representational point.

b) A single “protrusion” extends upwards from a centre point and is not individuated or enclosed. Score: 1 Faithful point.

3. ‘Arms’

a) Two lines or separate enclosed shapes (e.g. ovals) extend outwards from the sides of a central shape or a vertical line (one either side of centre). Score: 1 Representational point.

b) Two protrusions extend outwards (one each side) of a central mass and neither are individuated/enclosed. Score: 1 Faithful point.

4. ‘Legs’

a) Two lines or separate enclosed shapes (e.g. ovals) extend downwards from the bottom of a central shape or vertical line. Score: 1 Representational point.

b) Two protrusions extend downwards from the bottom of a central mass and neither are individuated/enclosed. Score: 1 Faithful point.

5. ‘Face’

a) Drawing includes internal detail resembling a facial configuration (i.e. 2 eyes, nose and mouth). Detail must be located either in enclosed ‘head’ at the top of the drawing, or in the central shape if no ‘head’ is present. Score: 2 Representational points.

b) Drawing does not contain any internal detail. Score: 2 Faithful points.

2.4.3 Reliability. Every drawing was coded by the first experimenter and an independent rater with related postgraduate experience. The second rater was blind to the objectives of the experiment and the details of each artist (e.g. their age, experimental condition, whether or not they named the stimuli). Reliability of coding schemes was assessed via Cohen's Kappa, which was calculated based on the two raters' categorical classifications (i.e. whether a drawing was Representational, Faithful or Uncodable). High interrater reliability was achieved for all coding schemes (man: $\kappa = .83$, $p < .001$; face: $\kappa = .92$, $p < .001$; sun: $\kappa = .83$, $p < .001$; kite: $\kappa = .84$, $p < .001$). Disagreements in categorical classifications (e.g. Faithful vs. Uncodable) were resolved by consensus between the two raters.

3. Results

Two sets of analyses were conducted. The first set addresses children's verbal responses. In order to identify age-related differences in typical development and identify the impact of ASD, the two groups of TD children and children with ASD were directly compared. The second set focuses on children's drawing responses, and their relation to verbal responding and experimental condition. Here we conduct two Generalized Linear Mixed-effects Models – one incorporating the effect of chronological age on the responses of TD children, and another comparing the responses of children with ASD and a subset of TD participants matched on receptive language.

3.1 Verbal responses

All responses could be unambiguously allocated to one of the coding categories detailed above. For every child, the number of responses (out of 4) belonging to each category was calculated (see Table 1).

Table 1. Verbal responses of TD 2- and 3-year-olds, TD 4- and 5-year-olds, and children with ASD in the Intentional and Accidental Conditions.

		Verbal response (*SD*)			
Group	Condition	Shape *M*	Material *M*	Do Not Know *M*	Other *M*
TD 2- & 3-year-olds	Intentional	3.44 (0.73)	0.44 (0.63)	0.06 (0.25)	0.06 (0.25)
	Accidental	1.88 (1.2)	1.93 (1.34)	0.06 (0.25)	0.13 (0.34)
TD 4- and 5-year-olds	Intentional	3.5 (0.73)	0.5 (0.73)	0 (0)	0 (0)
	Accidental	2.06 (1.29)	1.94 (1.29)	0 (0)	0 (0)
ASD	Intentional	2.2 (1.23)	1.6 (1.26)	0.2 (0.42)	0 (0)
	Accidental	2.1 (1.52)	1.7 (1.49)	0.2 (0.63)	0 (0)

Given the low rates of Do Not Know and Other responses across age groups and conditions, these data were omitted from subsequent analyses. The proportion of trials that children made Shape responses was calculated, and these proportion data were entered into a 3(Group: 2- and 3-year-olds, 4- and 5-year-olds, ASD) x 2(Condition: Intentional, Accidental) univariate ANOVA. The analyses revealed a significant effect of Condition, $F(1, 78) = 16.29$, $MSE = .082$, $p < .001$, $\eta p^2 = .17$, indicating that children made a significantly higher proportion of Shape responses in the Intentional condition than the Accidental condition (and therefore made a significantly greater proportion of Material responses in the Accidental condition than the Intentional condition). As the Group x Condition interaction approached significance, $F(2, 78) = 2.66$, $MSE = 0.82$, $p = .076$, $\eta p^2 = .06$, and we had a priori expectations that the ASD group would perform differently, we conducted a series of Bonferroni-adjusted pairwise tests. In the Intentional condition, the proportion of Shape responses made by children with ASD was significantly lower than that of the TD 2- and 3-year olds ($p = .004$) and the TD 4- and 5-year-olds ($p = .005$) who did not differ ($p = .99$), $F(2, 39) = 7.07$, $MSE = .048$, $p = .002$, $\eta^2 = 0.26$. In the Accidental Condition, all three groups produced similar proportions of Shape responses. Between-condition comparisons showed that the TD 2- and 3-year-olds, $F(1, 30) = 16.43$, $MSE = .07$, $p < .001$, $\eta^2 = 0.35$, and TD 4- and 5-year-olds, $F(1, 30) = 15.06$, $MSE = 0.07$, $p = .001$, $\eta^2 = 0.33$, produced a significantly higher proportion of Shape responses in the Intentional condition than the Accidental condition, while the responding of children with ASD did not differ between conditions. Interestingly, 16 out of 20 children with ASD named shape or material on at least 3 out of 4 trials. In the Intentional condition, 4 children with ASD showed a bias for symbolic shape-based naming, and 4 showed a bias for non-symbolic material responding. In the Accidental condition, 5 children with ASD showed a shape naming bias and 3 showed a material naming bias. Thus, roughly equivalent numbers of children in each condition consistently named shape or material without considering whether stimuli were intended to be representational. It is noteworthy that children in the ASD group with shape and material naming biases did not differ on chronological age, receptive vocabulary or autism severity.

The relationships between group characteristics and picture labelling were also assessed. For TD children, neither chronological age nor receptive vocabulary significantly correlated with proportion of symbolic Shape responses in either condition. As the preceding analyses showed that the verbal labelling of children with ASD was not influenced by representational intentions, the Intentional and Accidental conditions were collapsed. For the full sample of children with ASD, neither chronological age nor receptive vocabulary significantly correlated with proportion of Shape responses.

3.2 Drawing responses

As almost every drawing produced by 2-year-olds was classified as Uncodable, these responses were omitted from the following analyses. Compared to the older children, it is likely that the 2-year-olds' level of drawing development and/or motor coordination skills were insufficient for the task (Jolley, 2010). Thus, the drawings of children aged 3- to 5-years were examined. There were 16 three-year-olds, 16 four-year-olds and 16 five-year-olds. Every TD child produced drawings of all 4 ambiguous figures, with the exception of one 3-year-old in the Accidental condition who did not draw the figure resembling a man. As three children with ASD provided verbal responses but refused to make drawings, there was 17 children in the ASD group (*M* age: 10;3, *SD*: 3;4, *M* BPVS age: 4;6, *SD*: 1;1). One child with ASD in the Accidental condition refused to draw the figure resembling a man.

All drawing responses were categorised as Representational, Faithful or Uncodable. For every child, the number of responses (out of 4) belonging to each category was calculated (see Table 2). Our objective was to identify whether the creation of Representational and Faithful drawings was influenced by experimental condition (Intentional, Accidental), children's prior verbal labelling (Shape, Material), chronological age (for the TD children only) or diagnosis (TD vs ASD). To determine which combination of effects and interactions among these variables provides the best fit to the data, we conducted two sets of Generalized Linear Mixed-effects Models (GLMMs) – one examining the effects of Age, Condition and Verbal Response on the drawings of TD children, and one examining the effects of Diagnosis, Condition and Verbal Response on the drawings of children with ASD and an ability-matched sub-sample of TD controls. Following Baayen (2008; Baayen, Davidson, & Bates, 2008), both analyses incorporated random effects of participants and stimuli (trial type) on intercepts. In including these random intercepts terms, our analyses were specified to estimate the effects of theoretical interest while taking into account random variation among participants in levels of Representational drawing production or among stimuli in levels of Representational drawing elicited.

Table 2. Average frequencies of drawing responses (out of 4) produced by typically developing children and children with ASD in the Intentional and Accidental Conditions

		Drawing Response *(SD)*		
Group	Condition	Representational *M*	Faithful *M*	Uncodable *M*
TD 3-year-olds	Intentional	2.5 (1.41)	0.25 (0.46)	1.25 (1.39)
	Accidental	1.13 (1.13)	0.38 (0.52)	2.37 (1.5)
TD 4-year-olds	Intentional	2 (0.53)	1.37 (0.92)	0.63 (1.060
	Accidental	1.80 (0.92)	1.7 (0.53)	0.5 (0.74)
TD 5-year-olds	Intentional	1.75 (1.16)	1.88 (1.36)	0.37 (1.06)
	Accidental	0.62 (0.52)	3.25 (0.71)	0.13 (0.35)
ASD	Intentional	1.5 (1.69)	2 (1.93)	0.38 (0.74)
	Accidental	1.11 (0.78)	1.44 (0.47)	1.44 (1.24)

Note: The values for TD 3-year-olds and children with ASD in the Accidental condition do not sum to 4 because one child in each group refused to draw on 1 trial.

3.2.1 TD children. As we were specifically interested in the influence of prior Shape and Material naming responses on the production of Representational and Faithful drawings, drawings rated as Uncodable and those that were preceded by either a Do Not Know or Other verbal response were omitted, leaving 146 drawings (observations) in the analysis. The analysis modelled the probability (log odds) of creating a Representational drawing, considering variation across participants and trial type (random effects), as well as the fixed effects of Age in months (continuous variable), Condition (dichotomous variable), and Verbal Response (dichotomous variable), plus interactions between these variables.

We stepped through a series of GLMMs that estimated the impact of Age and experimental Condition on the log odds of drawings being Representational (more perceptually similar to the symbolised referent). Note that in each model, all fixed effects were entered simultaneously. Model 1 was a “null model” containing only the random effects of participants and stimuli on intercepts. Model 2 added main effects of Age, Condition and Verbal Response. Model 3 then added both Age x Condition and Age x Verbal Response interactions. Model 4 included the Age x Condition x Verbal Response interaction. By comparing simpler models (e.g. a model with just main effects) with more complex models (e.g. a model with main effects and interactions) we are able to examine if the increased complexity associated with additional terms improved the capacity of the model to fit the observed responses. We evaluated the relative utility of each increment in model complexity using likelihood ratio tests (see Baayen, 2008 and Snijders & Bosker, 2012, for examples). These indicated that inclusion of the main effects in Model 2 yielded a significant improvement in fit over the null model, χ^2 (3) = 40.59, p = 8 x10^{-9}, but adding the two-way (Model 3; p = .96) or three-way (Model 4; p = .22) interactions did not improve fit. Thus, Model 2 provided the most parsimonious explanation of the observed data (see Table 3).

Table 3. Summary of the Generalized Linear Mixed-effects Model of (log odds) Representational drawing in typically developing children as predicted by Age (months), Condition (Intentional, Accidental) and Verbal Response (Shape naming, Material naming); note that the Accidental condition and Material verbal response are taken as reference levels

Fixed effects	Estimated coefficient	Std. error	Z	Pr(>|z|)
(Intercept)	8.33	1.8	4.62	<.001***
Age (months)	- 0.16	0.03	-5.14	<.001***
Condition (Intentional)	1.23	0.43	2.87	0.004**
Verbal Response (Shape naming)	0.3	0.49	0.65	0.52
Random effects	Variance	Std. Dev		
Subject effect	<0.0001	<0.0001		
Trial type	0.46	0.68		
	AIC	BIC	logLik	deviance
	165.3	183.2	-76.6	153.3

In line with our hypotheses, the results demonstrate that TD children's graphic copying of ambiguous pictures is influenced by chronological age and whether or not they are created intentionally. TD children were more likely to produce perceptually accurate Faithful drawings with age. The descriptive statistics in Table 2 clearly show that 3-year-olds produced higher frequencies of Representational drawings than Faithful drawings, whereas 5-year-olds produced higher frequencies of Faithful drawings than Representational drawings. The model also revealed that the Intentional Condition elicited a significant increase in the probability of creating Representational drawings, indicating that children's sensitivity to artists' intentions influences the nature of their graphic copies. Interestingly, the model did not identify a predictive relationship between children's verbal and drawing responses.

However, the fact that the Age x Condition interaction introduced in Model 3 did not significantly improve fit is puzzling given the distribution of Representational and Faithful drawings produced by the TD children. Table 2 shows that 3-year-olds produced almost exclusively Representational drawings in both conditions, the 4-year-olds produced roughly similar frequencies of Representational and Faithful drawings in both conditions, and the 5-year-olds produced the hypothesised pattern (i.e. relatively more Representational drawings in the Intentional condition vs the Accidental condition, and relatively more Faithful drawings in the Accidental condition vs the Intentional condition). Indeed, when these age groups are analysed separately, the relation between Condition and Drawing is significant for 5-year-olds, X^2 (2, N = 60) = .7.16, p = .007, but not 3-year-olds (Fisher's Exact = .59, non-sig.) or 4-year-olds (X^2= .73, p = .79). Thus, contrary to the model's output, the relation between Condition and Drawing Response actually differs between age groups – only the 5-year-olds' drawings were significantly influenced by artists' representational intentions. By contrast, separate analyses for each age group examining the relation between Verbal Responding and Drawing Responding yielded no differences.

Finally, to establish whether the drawings of the TD children differed in quality across age groups or experimental conditions, the frequencies of Uncodable responses were entered into a 3(Group: 2- and 3-year-olds, 4- and 5-year-olds, ASD) x 2(Condition: Intentional, Accidental) univariate ANOVA. The analyses revealed a main effect of Group, $F(2, 42) = 8.97$, $MSE = .10.65$, $p = .001$, $\eta p^2 = .3$, indicating that 3-year-olds made significantly more Uncodable drawing responses than 4- and 5-year-olds, who did not differ (see Table 2). There was no effect of Condition and no interaction, suggesting that differences in the frequencies of Uncodable drawings between the Intentional and Accidental condition were not significant for any age group.

3.2.2 ASD vs. TD. To assess whether the responding of children with ASD was qualitatively atypical, it was necessary to include both populations within the same model. As the receptive language ability of children with ASD who produced drawings fell between that of the TD 3- and 4-year-olds, we created a control group consisting of the 8 3-year-olds (4 per condition) who scored highest on the BPVS and the 8 4-year-olds (4 per condition) who scored lowest. The mean receptive vocabulary age for this TD control group was 4;6 years (*SD* = 0;8) and was very well matched to the ASD group (*M* = 4;6, *SD* = 1;1).

As in the preceding analysis, drawings rated as Uncodable and those that were preceded by either a Do Not Know or Other verbal response were omitted, leaving 91 drawings (observations) in the analysis. The analysis modelled the probability (log odds) of creating a Representational drawing, considering variation across participants and trial type (random intercepts), as well as fixed effects of diagnostic Group (dichotomous variable), Condition (dichotomous variable) and Verbal Response (dichotomous variable), plus interactions between these variables.

We conducted a sequence of GLMMs that estimated the impact of Group and experimental Condition on the log odds of drawings being Representational. Note that in each model, all fixed effects were entered simultaneously. Model 1 was a “null model” containing only the random effects of subject and trial. Model 2 added main effects of Group, Condition and Verbal Response. Model 3 then added both Group x Condition and Group x Verbal Response interactions. Model 4 included the Group x Condition x Verbal Response interaction.

As above, we evaluated the relative utility of each increasingly-complex model using likelihood ratio tests. These indicated that inclusion of the main effects in Model 2 yielded a significant improvement in fit over the null model, χ^2 (3) = 18.41, $p < .001$, and adding the two-way interactions in Model 3 improved the fit further, χ^2 (2) = 10.06, $p = .006$. The addition of the three-way interaction (Model 4; $p = .59$) afforded no further improvement. Therefore, Model 3 provides the best fitting explanation of the observed data (see Table 4).

Table 4. Summary of the Generalized Linear Mixed-effects Model of (log odds) Representational drawing in children with autism and language-matched controls as predicted by Group (ASD, TD), Condition (Intentional, Accidental) and Verbal Response (Shape naming, Material naming); note that the ASD group, Accidental condition and Material verbal response are taken as reference levels

Fixed effects	Estimated coefficient	Std. error	Z	Pr(>|z|)
(Intercept)	-1.98	0.95	-2.08	0.037*
Group (TD)	1.17	1.28	0.92	0.36
Condition (Intentional)	-1.09	1.01	-1.08	0.28
Verbal Response (Shape naming)	3.65	1.25	2.93	0.003**
Group (TD) x Condition (Intentional)	3.55	1.56	2.28	0.022*
Group (TD) x Verbal Response (Shape naming)	-2.84	1.65	-1.73	0.08 (borderline)
Random effects	Variance	Std. Dev		
Subject effect	0.88	0.94		
Trial type	0.07	0.27		
	AIC	BIC	logLik	deviance
	115.1	135.8	-49.6	99.1

In support of our hypotheses, the GLMM suggests that children with ASD are less sensitive to representational intentions when copying ambiguous pictures. That is, being asked to draw meaningful communicative symbols in the Intentional Condition did not elicit the same increase in Representational drawings as for the TD comparison group. This is evident in the descriptive statistics (see Table 2) which show that children with ASD produced roughly similar frequencies of Representational and Faithful drawings in both conditions. However, compared with TD children, it appears that children with ASD tend to produce more Representational drawings after naming shape (borderline interaction, p = .08). Thus, for the ASD group, children's own verbal labelling had a greater influence on their drawings than the artists' underlying intentions. Together with the preceding analyses, these results indicate the opposite pattern of performance for TD children – their drawings were influenced more by representational intentions (they were more likely to produce Representational drawings in the Intentional Condition and Faithful drawings in the Accidental Condition) than their prior verbal labelling.

To identify whether the drawings of the ASD group differed in quality between experimental conditions, the frequencies of Uncodable responses were entered into an independent-samples t-test (Condition was the between-subjects factor). The t-test bordered on significance, $t(15) = -2.13$, $p = .051$, $d = 1.04$, suggesting that children with ASD tended to produce more Uncodable drawing responses in the Accidental condition than the Intentional condition.

To clarify the influence of prior verbal responding on the drawings of children with ASD, we examined the response patterns of children previously identified as having a shape or material naming bias.[2] Within this sub-sample, each trial was assigned to one of 6 categories depending on the child's corresponding verbal (Shape, Material) and drawing

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[2] Within the ASD group, 1 child with a shape naming bias and 2 with a material naming bias did not produce any drawings.

(Representational, Faithful, Uncodable) responses (see Table 5). Children with a shape naming bias produced Representational drawings on 45% of trials and Faithful drawings on 29% of trials, while children with a material naming bias produced Faithful drawings on 45% of trials and Representational drawings on 25% of trials. More importantly, across the entire sample of children with ASD, significantly more trials including codable drawings fit the hypothesised verbal-drawing predictive relationship (i.e. Shape-Representational, Faithful-Material; $N = 37$), than did not (i.e. Shape-Faithful, Material-Representational; $N= 12$), X^2 (1, N = 49) = 12.76, $p < .001$. By contrast, when we consider the influence of representational intentions on the entire sample of children with ASD, similar frequencies of trials including codable drawings fit the hypothesised condition-drawing predictive relationship (i.e. Intentional-Representational, Accidental-Faithful; $N = 26$) as did not (i.e. Intentional-Faithful, Accidental-Representational; $N = 23$). Thus, it is clear that the prior verbal labelling of children with ASD influences their subsequent drawing of ambiguous pictures, but artists' representational intentions do not.

Table 5. Patterns of naming and drawing responses by children with ASD identified as having a shape or material naming bias.

Bias	S-R	S-F	S-U	M-R	M-F	M-U
Shape naming	14 (45%)	6 (19%)	6 (19%)	0 (0%)	3 (10%)	2 (6%)
Material naming	2 (10%)	1 (5%)	0	3 (15%)	8 (40%)	6 (30%)

Note: S-R: Shape-Representational; S-F: Shape-Faithful; S-U: Shape-Uncodable; M-R: Material-Representational; M-F: Material-Faithful; M-U: Material-Uncodable.

4. Discussion

The present study investigated whether children's naming and drawing of pictures is influenced by representational status, as determined by an artist's intentions. TD children aged 2- to 5-years and children with ASD were shown a series of line drawings roughly shaped like familiar nameable objects, and were informed that the figures had been created intentionally or by accident. At test, participants were asked to name the pictures, and then draw them. Our results indicate that picture comprehension in TD children is not mediated exclusively by shape. In the Intentional condition, all TD children produced significantly higher proportions of symbolic naming responses than non-symbolic material responses, but in the Accidental condition, these responses were produced at similar rates. Hence, our data support the theory that, from 2-years of age, TD children reliably name shape only when it provides an index of representational intent (Bloom & Markson, 1998; Gelman & Ebeling, 1998). By contrast, children with ASD were equally likely to label shape or material irrespective of whether ambiguous figures were intentional representations. The drawing data indicated that graphic copying in TD children is mediated by chronological age and, by 5 years, the representational intentions underlying the to-be-copied figure. While the TD children produced more Faithful drawings with age, the Intentional Condition elicited an increase in Representational drawings (canonical depictions of symbolised referents) in the eldest group. Interestingly, the drawings of the ASD group were influenced by children's own verbal labelling. Overall, these findings suggest that representational intentions mediate how TD children, but not children with ASD, name and copy pictures.

In line with previous evidence (Bloom & Markson, 1998; Gelman & Ebeling, 1998), our data show that young TD children reflect on whether 2-D markings are intended to be representational before assigning an object name based on shape. When such markings are created by accident, they often regard them as non-symbolic, and can refrain from naming shape. The observed effect of representational status replicates Gelman and Ebeling's (1998) findings almost perfectly, and supports Bloom and Markson's (1998) claim that TD children name shape when they infer it to be a reliable cue to referential intent (e.g. children are much more likely to name a car-shaped drawing "a car" than a car-shaped paint spill). Thus, at a theoretical level, this study demonstrates that TD children do not always name the shapes of pictures – they name the *referents* that those shapes are intended to represent. Conversely, our study argues against Browne and Woolley (2001) who propose that children's picture comprehension is entirely resemblance-based. It is noteworthy that their study employed pictures that unambiguously resembled familiar nameable objects other than their intended referents, thus presenting participants with an unusual and confusing test situation. This problem is avoided here by using ambiguous pictures; while each figure resembled a familiar nameable object, the degree of iconicity was low enough for it to be believable that resemblance could be incidental. Consequently, children in the Accidental Condition, who experienced conflict between shape and representational status, were not biased towards shape-based naming.

As predicted, and in accord with previous descriptions of children's drawing development (Cox, 1992, 2005; Golomb, 2002, 2004; Jolley, 2010; Luquet, 2001), TD children showed an age-related transition from drawing what they *know* to drawing what they *see* when reproducing ambiguous figures. Irrespective of condition, TD 3-year-olds produced high frequencies of Representational and Uncodable drawings, but very low frequencies of Faithful drawings, while the 4-year-olds produced similar frequencies of Representational and Faithful drawings, and the 5-year-olds produced high frequencies of Faithful drawings. There are several possible explanations for these age differences. Firstly, the performance of the 3-year-olds could be attributable to differences in their freehand drawing and copying skills. Each of the pictures represented a familiar object that young children often practice drawing (person, face, sun, kite), thus when the 3-year-olds regarded the stimuli as symbols, they could produce Representational responses by activating well-practiced drawing scripts and adopting a ‘content-directed’ strategy (Chen & Cook, 1984). However, when the stimuli were perceived as non-symbolic, their attempts to produce Faithful reproductions were likely hindered by their insufficient graphic copying skills, resulting in high frequencies of Uncodable drawings (particularly in the Accidental condition). By contrast, the 4- and 5-year-produced far fewer Uncodable responses and increasing frequencies of Faithful drawings, indicating their more advanced graphic copying skills and increasing use of a ‘structure-directed’ strategy focussing primarily on the to-be-copied image, rather than the symbolised referent (Chen & Cook, 1984).

Secondly, the drawing responses of TD children may have been influenced by their judgements about the experimenter’s expectations. When the 3-year-olds were assigned the goal of reproducing an image of a familiar object, their primary concern may have been to create a drawing that was clearly recognisable to the experimenter, thus necessitating the inclusion of category-defining features associated with the label (Bremner & Moore, 1984). By contrast, the 5-year-olds may have been increasingly focussed on producing perceptually accurate copies, even when they regarded the ambiguous figures as symbols for familiar, nameable, objects. Finally, the drawings of the TD children may have been influenced by their comprehension of the test question “can you draw this?” (Freeman, 1991; Cox, 1992). The youngest children may have taken the word *this* to mean the symbolised object (i.e. “can you draw a kite?” or “can you draw what you *see* in this picture?”), while the older children may have interpreted the question more literally (i.e. “can you draw this specific picture?”). While it is impossible for us to quantify the relative contribution of each potential influence on the TD children’s drawings, our findings indicate a clear age-related shift in how young

TD children reproduce ambiguous pictures – they initially focus on representing symbolic content, but increasingly focus on preserving perceptual accuracy.

Alongside the effect of age, the graphic copies of TD children were influenced by representational intent, but *not* their own verbal labelling. The GLME model indicated that the TD children were relatively more likely to produce Representational drawings in the Intentional condition, and Faithful drawings in the Accidental condition. However, when the relation between Condition and Drawing Response was analysed separately for each age group, only the 5-year-olds' drawings were significantly influenced by representational intentions. By effectively drawing the referents that shapes were intended to represent, rather than the shapes themselves, children provided converging evidence that they derive referential meaning from artists' intentions. However, the fact that even 2- and 3-year-old TD children were sensitive to representational intentions when naming ambiguous shapes suggests that the influence of intentions on graphic copying is not straightforward. It is likely that an interaction between intentional understanding and drawing ability drove the observed age effect. Contrary to our predictions, TD children's prior verbal labelling did not mediate the way they depicted ambiguous figures. This may indicate that even young TD children understand that the meaning of a pictorial representation is not determined by the perception of the viewer (Bloom & Markson, 1998; Callaghan & Rochat, 2008). Furthermore, the finding that older children (particularly 5-year-olds) often produced Faithful drawings after naming shape could indicate an increasing awareness that artists might *intend* to create abstract or less-iconic pictures, thus directing children to produce perceptually accurate copies that conform to those inferred intentions.

Unlike the TD children, children with ASD were not sensitive to representational intentions when naming or drawing ambiguous figures. Regardless of whether a picture was created intentionally or by accident, children with ASD were equally likely to perceive it as a symbolic object (naming shape) or a non-symbolic object (naming material). The fact that intentionality did not increase shape-based naming in children with ASD suggests that this population may not understand that communicative intentions confer symbolic status to visual representations. Indeed, over 75% of the ASD consistently named either shape or material (bias types were equally frequent in both conditions) without considering whether stimuli were intended to be representational. Our finding that the drawings of children with ASD were influenced by their verbal responding, rather than representational status, provides additional evidence that this population derive meaning from pictures in an egocentric, non-intentional, manner. Unlike TD 5-year-olds, who created increased proportions of Representational drawings in the Intentional Condition (i.e. they drew a more face-like picture when they inferred that a figure's *creator* had intended to represent a face), children with ASD tended to create Representational drawings after naming shape (i.e. they drew a more face-like picture when they *themselves* decided that a figure was a face). However, from the current data, it is impossible to distinguish whether the verbal labels *or* children's internal appraisal of the depicted content was responsible for the relationship between naming and drawing responses in the ASD group. For example, it is possible that children with ASD drew "a man" because they *thought* the drawing was "a man", rather than because they named it a "man". In this scenario, verbal labelling merely serves as an indicator of children's internal appraisal, and is not itself the cause of the canonical drawing. Future research is required to disentangle the relationship between internal judgements of content, verbal labelling and drawing by comparing graphic copies created by children before and after naming. Another puzzling finding was that children with ASD produced significantly more Uncodable drawings in the Accidental condition than the Intentional condition. One possibility is that children in the Accidental condition were trying to make the stimuli more perceptually similar to the constituent materials (e.g. more mud-like), however, further work is required to validate this speculation.

Research investigating the acquisition of pictorial understanding has shown that social-cognitive skills (e.g. intention reading and imitation) enable TD children to learn about pictures through interactions with more experienced symbol-users (Callaghan & Rankin, 2002; Callaghan & Rochat, 2008; Callaghan et al., 2004; Rochat & Callaghan, 2005). However, many children with ASD show deficits in the social-cognitive skills that underlie pictorial development, such as imitation and intention reading (Baron-Cohen, 1995; Charman et al., 1997; Griffin, 2002; Hobson, 2002; Mundy & Willoughby, 1996), possibly preventing them from inferring representational intentions from others' communicative actions involving pictures. If children with ASD cannot acquire pictorial understanding through social interactions, perhaps they develop an understanding of pictures via an alternative non-intentional pathway (Hartley & Allen, 2014). Moreover, the atypical performance of children with ASD in this study provides converging support for the theory that normative picture comprehension integrates intention reading processes (at least in certain circumstances). In situations where resemblance is an inadequate cue to a 2-D shape's meaning, it appears that young TD children spontaneously reflect on the intentions of its creator to establish (a) whether the shape is in fact a symbolic representation (shown by the present study), and (b) what the intended referent is (Hartley & Allen, 2014). Conversely, impairments in social-cognition may inhibit children with ASD from reflecting on intentional cues, perhaps eliciting a decontextualized and egocentric interpretation.

Of course, we must address the limitations of this research. Although the children with ASD were matched on receptive language to TD peers, they may not have understood the social-pragmatics underlying the stories. However, the stories were worded specifically to tap children's understanding of whether representational intentions confer symbolic status to pictures. If the autism group failed to understand the intentional language, it is highly probable that they are not reflecting on pictures as intentional creations of others (Hartley & Allen, 2014). It is also possible that some Material naming responses were due to echolalia – the tendency to repeat recently-heard words and phrases. However, the influence of echolalia was likely minimal because (a) more than 50% of verbal responses were shape names, and (b) there would have been instances of children echoing other words in the stories (e.g. the protagonists name), leading to increased rates of “Other” responses. We acknowledge that the atypical responding of the ASD group may have been due to general developmental delay, rather than autism per se. Including an ability-matched sample of children with major learning disabilities would have enabled us to address this distinction. However, children with ASD were included in this study to corroborate the role of intentional reasoning in *typical* picture comprehension, and it should be the objective of future research to elucidate the specific origins of their picture comprehension difficulties.

It is important to note that the drawing data is less clear-cut and more complex to interpret than the naming data due to variation in drawing ability, theory of mind, and possible differences in children’s comprehension of the test question. However, the responding of TD 5-year-olds and the children with ASD broadly supported our hypotheses concerning the influence of representational intentions on children’s graphic copying. As we propose that the contrasting response patterns of TD children and children with ASD are caused by differences in intention reading, this study would have benefited from an additional measure of this ability. Thus, despite the fact that deficits in intention reading are well-documented in ASD (Allen, 2009; Baron-Cohen et al., 1997; Charman et al., 1997; D’Entremont & Yazbek, 2007; Griffin, 2002; Hartley & Allen, 2014; Hobson, 2002; Preissler & Carey, 2005), our theoretical explanations should be treated with caution. Similarly, it would have been valuable to measure participants’ nonverbal ability to test whether this skill contributed to differences in performance, particularly concerning children's drawing responses. The importance of this weakness is reduced by previous evidence that nonverbal ability does not significantly predict typical development in the pictorial domain (including graphic production; Kirkham, Stewart & Kidd, 2012), therefore limiting its relevance to the ASD group only. Lastly, it would have been beneficial to assess whether all participants were capable of drawing the stimuli in a canonical fashion. Perhaps some children (particularly in the ASD group) produced low frequencies of Representational drawings because they were unable to produce iconic drawings of the referent objects. However, all of the depicted objects were common referents of children's free drawings (Cox, 2005), and previous studies have shown that the free drawings of children with ASD are at least as iconic as those of ability-matched controls (Charman & Baron-Cohen, 1993).

5. Conclusions

Overall, the present study has shown that representational status significantly mediates how TD children, but not children with ASD, name and draw ambiguous pictures. The tendency of TD 2- to 5-year-olds to name a picture's shape is influenced by whether or not the artist *intended* that shape to be representational. Additionally, TD 5-year-olds (but not 3- or 4-year-olds) were more likely to produce canonical drawings of symbolised referents when they believed that stimuli were intended to be symbolic, further demonstrating their sensitivity to representational intentions underlying pictures. Thus, picture comprehension in typical development is not driven entirely by resemblance – the meaning of a given shape is determined by the intentions of its creator. By contrast, the naming and drawing responses of children with ASD were not influenced by the social-communicative intentions underlying pictures. Rather, impairments in social-cognition may prevent children with ASD from spontaneously reflecting on representational intentions, resulting in an egocentric style of picture comprehension (Hartley & Allen, 2014). Further research is required to elucidate important differences in the development of pictorial understanding between typically developing children and children with ASD.

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7. Appendix A. Stories corresponding to each ambiguous picture (I = Intentional; A = Accidental) (see Fig. 1)

Picture 1 (man).	I: When John was painting in an art lesson, he used some paint to make something for his teacher. This is what it looked like. A: When John's dad was painting the house, John accidentally spilled some paint on the floor. This is what it looked like.
Picture 2 (face).	I: Tommy had peas with his dinner one night. He didn't like the way they tasted, so he pushed them around on his plate to make a picture. This is what it looked like. A: Tommy had peas with his dinner one night. He tried to eat them with a fork, but some of them rolled off his fork onto the floor. This is what it looked like.
Picture 3 (sun).	I: One day, while he was in an art lesson, Mike got to use mud to make an art project. Mike carefully put the mud on the paper until he was finished. It looked like this. A: One day, while he was playing, Mike saw a big puddle. Mike jumped in the puddle and the mud splashed on his shirt. It looked like this.
Picture 4 (kite).	I: While looking through a scrap box, Dave found some string and decided to make an art project. It looked like this. A: While walking through his front yard, David found some string caught on a bush. It looked like this.

8. Appendix B. Coding schemes for children's drawings

Picture 1 (man).

1. 'Uncodable' – drawing does not, in any way, share perceptual similarity with either stimuli or symbolised referent (e.g. drawing is a scribble or series of randomly-placed disconnected shapes). If drawing does not fulfil criteria for Uncodable classification, proceed with coding.

2. 'Head'

a) Enclosed circular shape located at the top of the drawing. May be attached to a central shape or a vertical line. Score: 1 Representational point.

b) A single "protrusion" extends upwards from a centre point and is not individuated or enclosed. Score: 1 Faithful point.

3. 'Arms'

a) Two lines or separate enclosed shapes (e.g. ovals) extend outwards from the sides of a central shape or a vertical line (one either side of centre). Score: 1 Representational point.

b) Two protrusions extend outwards (one each side) of a central mass and neither are individuated/enclosed. Score: 1 Faithful point.

4. 'Legs'

a) Two lines or separate enclosed shapes (e.g. ovals) extend downwards from the bottom of a central shape or vertical line. Score: 1 Representational point.

b) Two protrusions extend downwards from the bottom of a central mass and neither are individuated/enclosed. Score: 1 Faithful point.

5. 'Face'

a) Drawing includes internal detail resembling a facial configuration (i.e. 2 eyes, nose and mouth). Detail must be located either in enclosed 'head' at the top of the drawing, or in the central shape if no 'head' is present. Score: 2 Representational points.

b) Drawing does not contain any internal detail. Score: 2 Faithful points.

Picture 2 (face).

1. ‘Uncodable’ – drawing does not, in any way, share perceptual similarity with either stimuli or symbolised referent (e.g. drawing is a scribble or series of randomly-placed disconnected shapes). If drawing does not fulfil criteria for Uncodable classification, proceed with coding.

2. ‘Eyes/nose’

a) Three markings (e.g. combination of circles, ovals, lines and dots) positioned in an inverted triangle configuration. If the top two markings are circles, they must include internal detail (e.g. dots). Score: 1 Representational point.

b) Three circles positioned in an inverted triangle configuration. Circles contain no internal detail. Score: 1 Faithful point.

3. ‘Mouth’

a) An unbroken line is positioned below the inverted triangle markings. The line curves upwards at both ends. Score: 4 Representational points.

b) An unbroken line is positioned below the inverted triangle markings. The line is flat (horizontal). Score: 2 Representational points.

c) A row of individual, enclosed, rounded shapes or dots are positioned in a row below the inverted triangle markings. The row is flat (horizontal). Score: 2 Faithful points.

d) A row of individual, enclosed, rounded shapes or dots are positioned in a row below he inverted triangle markings. The row is horizontal and curves upwards at both ends. Score: 4 Faithful points.

Picture 3 (sun).

1. ‘Uncodable’ – drawing does not, in any way, share perceptual similarity with either stimuli or symbolised referent (e.g. drawing is a scribble or series of randomly-placed disconnected shapes). If drawing does not fulfil criteria for Uncodable classification, proceed with coding.

2. ‘Central shape’

a) Central shape is uniformly rounded (e.g. circle, oval) with no internal detail or detail resembling a facial configuration. Score: 1 Representational point.

b) Central shape is not smoothly rounded (i.e. it’s “dented”) and contains no internal detail. Score: 1 Faithful point.

3. ‘Outer shapes’

a) The outer shapes are wiggly or straight lines that extend outwards from the central shape. Score: 4 Representational points.

b) The majority of the outer shapes are roughly circular and are attached to the central shape. Score: 2 Representational points.

c) The majority of the outer shapes are roughly circular and are detached from the central shape. Score: 2 Faithful points.

d) The majority of the outer shapes are ovals or tear-drops and are detached from the central shape. Score: 4 Faithful points.

Picture 4 (kite)

1. ‘Uncodable’ – drawing does not, in any way, share perceptual similarity with either stimuli or symbolised referent (e.g. drawing is a scribble or series of randomly-placed disconnected shapes). If drawing does not fulfil criteria for Uncodable classification, proceed with coding.

2. ‘Kite’

a) Drawing includes an enclosed shape that does not have 4 sides (e.g. circle, oval). Must be connected to a line extending away/downwards from the shape. Score: 3 Representational points.

b) Drawing includes an enclosed shape that has 4 straight sides. Must be connected to a line extending away/downwards from the shape. Score: 3 Faithful points.

3. ‘String

a) Line extending downwards from enclosed shape is straight. Score: 2 Representational points.

b) Line extending downwards from enclosed shape has 1-2 undulations. Score: 2 Faithful points.

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