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A novel social attribution paradigm: The Dynamic Interacting Shape Clips (DISC)

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ABSTRACT

The Dynamic Interacting Shape Clips (DISC) is a novel stimulus set designed to examine mentalizing, specifically social attribution, suitable for use with diverse methodologies including fMRI. The DISC offer some advantages compared to other social attribution stimuli including a large number of stimuli, subsets of stimuli depicting different kinds of social interactions (i.e., friendly approach, aggression, and avoidance), and two control tasks–one that contrasts interpretations of socially contingent movement versus random, inanimate movement, and the other that examines the impact of attentional shifts on mentalizing using the same visual stimuli with a different cue. This study describes both behavioral and fMRI findings from a sample of 22 typically developing adults (m_{age} = 21.7 years, SD = 1.72). Behavioral data supports participants anthropomorphized the stimuli and the social intent of the clips were perceived as intended. Neuroimaging findings demonstrate that brain areas associated with processing animacy and mental state attribution were activated when participants were shown clips featuring social interactions compared to random movement, and when attention was cued to social versus physical aspects of the same stimuli. Results lend empirical support for the use of the DISC in future studies of social cognition.

1. Introduction

Mentalizing, or the ability to make mental state attributions including beliefs, feelings, and desires, allows for humans to explain and predict behavior in others (Premack & Woodruff, 1978). This social cognitive process is vital for successful human interaction and is compromised in psychiatric and neurological conditions marked by deficits in social functioning such as autism spectrum disorder (Happe, 1995), schizophrenia (Bell, Fiszdon, Greig, & Wexler, 2010; Horan et al., 2009), brain injury (Heberlein & Adolphs, 2004; Scheibel et al., 2011), and neurodegenerative disorders (Eddy & Rickards, 2015). Many of the well-studied mentalizing paradigms are limited by a dichotomous response indicating whether a participant has attributed a false belief to another person (i.e., "Does person A think object B is in location C or D?"), which was influenced by the traditional understanding that mentalizing required the appreciation of a false belief (Bennett, 1978; Dennet, 1978). More recent paradigms have been developed to study a broader range of mental states and literature is emerging highlighting the complexity underlying the behavioral manifestation, developmental trajectory, cognitive processes, and neural foundations of mentalizing. This paper presents a novel stimulus set, the Dynamic Interacting Shape Clips (DISC), which targets a specific aspect of mentalizing called social attribution, and was designed to address many of the limitations of traditional mentalizing tasks and current social attribution paradigms. The DISC have utility for the study of social attribution in behavioral and fMRI paradigms and are suitable for use in a broad range of clinical

Abbreviations: DISC, Dynamic Interacting Shape Clips; VMPFC, ventromedial prefrontal cortex; DMPFC, dorsomedial prefrontal cortex; IFG, inferior frontal gyrus; FG, fusiform gyrus; TP, temporal pole; STS, superior temporal sulcus; STG, superior temportal gyri; TPJ, temporoparietal junction; EC, extrastriate cortex; PCC, posterior cingulate cortex; IPC, inferior parietal cortex

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and non-clinical populations.

Social attribution is a specific kind of mentalizing occurring in the context of anthropomorphization, or the attribution of human features to non-human stimuli, based on movement cues. The term social attribution was coined by Klin (2000) and influenced by a classic study by Heider and Simmel (1944): Participants watched a 2.5-minute video featuring animated geometric shapes scripted to follow social scenarios, including a game of leapfrog, a fight, and a love triangle. Ninety-seven percent of participants spontaneously attributed human characteristics to the shapes, including mental states, and described the shapes within an overarching social context. This study has been cited more than 2000 times and a number of adaptations of the original paradigm have been developed.

There are several advantages to using social attribution measures rather than false belief tasks to measure mentalizing. For example, the ambiguous nature of the social attribution paradigm reduces the impact of performance facilitation through compensatory cognitive and linguistic mechanisms, which commonly occurs in false belief paradigms (Bloom & German, 2000; Klin, 2000; Wimmer & Perner, 1983) and performance on social attribution tasks is strongly correlated with social impairment in everyday life compared to false belief tasks where this relationship is less robust (Begeer, Bernstein, van Wijhe, Scheeren, & Koot, 2012; Happe, 1995; Klin, 2000; Senju, Southgate, White, & Frith, 2009). Beyond this, typically developing adults often show ceiling effects on false belief tasks, whereas coding schemes have been developed to quantify the sophistication of mentalizing during social attribution measures (Klin, 2000) and provide a continuous measurement of mentalizing across several dimensions. This dimensional approach is useful for exploring the range of social attribution in both typical and atypical populations and may provide the means to identify subtle changes associated with intervention (Hecht, Robins, Gautam, & King, 2017). Research has also shown that descriptions of social attribution scenes demonstrate similarities across cultures (Koelkebeck et al., 2011; Rime et al., 1985), which suggests that motion cues may be a universal aspect of social perception and have utility for the study of social cognition cross-culturally. Further, the developmental literature has also shown that the most basic foundations of social attribution develop as early as three months of age, as infants make social evaluations about “helping” and “hindering” shapes, which influence subsequent behavior (Hamlin et al., 2007, 2010), whereas typically developing youth typically do not show success on false belief tasks until the preschool years (Wellman, Cross, & Watson, 2001). This early age of onset suggests that social attribution tasks may measure processes that are important in the development of social cognition and that disruptions in the early development of this construct could serve as a useful early marker of conditions characterized by social impairment. Although humans are required to perceive and integrate many modalities of social information beyond motion in order to make social inferences in real world settings, research has shown that replacing the shapes with human silhouettes does not enhance performance (Rime et al., 1985). These findings indicate that social motion is likely a robust social perceptual cue even when additional social information is present. Thus, while social attribution tasks do not depict the richness of real-world social-perceptual stimuli, they provide an opportunity to examine an important aspect of mentalizing in a highly controlled manner.

Although there is clear utility for use of social attribution tasks within the study of mentalizing, and more broadly, social cognition, extant tasks are not without limitations. There are common features inherent across social attribution paradigms (i.e., ambiguous geometric shapes demonstrating animate and social movement); however, differences include how stimuli are presented and how and what data are collected. Unfortunately, the same stimuli have rarely been used across studies. One exception is the Social Attribution Task (SAT; Klin, 2000), which utilizes a portion of the stimuli developed by Heider and Simmel (1944) with a more complex and dimensional coding scheme. The SAT has been used in a number of behavioral studies and with diverse clinical samples (Bell et al., 2010; Van der Fluit, Gaffrey, & Klein-Tasman, 2012; Klin & Jones, 2006; Koenig, Klin, & Schultz, 2004; Scheibel et al., 2011). However, the SAT is limited by a single 50-second video and it is difficult to examine the shorter portions of the entire clip independently because each segment is related to the overall narrative, which could scaffold performance. Schultz et al. (2003) developed a thoughtful adaptation suitable for the fMRI environment, which includes eight new clips, each 15 s in length and featuring an independent social story. The control task, the bumper car task, features moving geometric shapes that do not depict a social story and require participants to make physical rather than social inferences. Schultz and colleagues noted while they attempted to use the same SAT clips for the bumper car task in piloting, participants reported it was difficult to stop thinking about the stimuli as social. Thus, the authors decided to use stimuli designed specifically for the bumper car task, which did not depict social movement, in order to reduce the amount of activation specific to social attribution during the control task. Results indicated that activations in the bilateral DMPFC, IFG, pars orbitalis, lateral orbital gyrus, STS, STG, as well as the right TP, amygdala, and FG were associated with processing of the social versus physical scenes. Ross and Olson (2010)’s replication of Schultz and colleagues’ work in adults and extension in school-aged children demonstrated similar findings. Drawbacks of these stimuli include the limited number of clips included in the stimulus set and the concern that the movement characteristics between the bumper car control condition and the social condition differed, therefore limiting interpretation of the differential neural activations to the social compared to the physical attributions. Despite these limitations, the bumper car task has been helpful in elucidating the neural correlates of social versus physical attribution in a number of clinical conditions (Eddy & Rickards, 2015; Schultz et al., 2003).

Several other groups have developed SAT-like stimuli suitable for the fMRI environment. Martin and Weisberg (2003) developed a set of sixteen 21-second clips featuring geometric shapes and demonstrated that clips featuring animate social action (e.g., dancing, swimming) were associated with activations in the bilateral FG (lateral) and STS, as well as the right amygdala and VMPFC when compared to similar clips featuring shapes depicting inanimate mechanical actions (e.g., billiards, bowling). Tavares, Lawrence, and Barnard (2007) cleverly cued participants to attend to either social or physical aspects of clips featuring geometric shapes moving in animate and/or socially contingent ways. When participants were cued to attend to social aspects versus physical aspects of the stimuli, increased activation in the bilateral amygdala, PCC, DMPFC, TP as well as the right FG, TPJ, and STS emerged. However, this task featured only two shapes in each scene, which may limit the complexity of potential social interpretation.

Another stimulus set, Tricky Triangles, has also been used to study social attribution in clinical populations (Abell, Happe, & Frith, 2000; Levin et al., 2011; Russell, Reynaud, Herba, Morris, & Corcoran, 2006). These stimuli include twelve 34 to 45-second clips each featuring two interacting triangles. An advantage of these stimuli is that each clip features a specific kind of movement: random (e.g., shapes bouncing off walls, drifting), goal-directed (i.e., fighting, following, chasing, dancing), or Theory of Mind movements (i.e., tricking, mocking, surprising, seducing). Several groups have examined these stimuli in imaging paradigms including PET (Castelli, Happé, Frith, & Frith, 2000; Castelli, Frith, Happé, & Frith, 2002) and fMRI (Gobbini, Koralek, Bryan, Montgomery, & Haxby, 2007; Ohnishi et al., 2004). Across studies, contrasting the animated clips with random movement revealed activations in frontal areas including medial prefrontal cortex and IFG, and temporal regions including the TP, FG, STS, and the inferior temporal gyrus, as well as the EC, inferior parietal lobule, precuneus, and cerebellum (Castelli et al., 2000, 2002; Gobbini et al., 2007; Ohnishi et al., 2004). Osaka, Ikeda, and Osaka (2012) developed a novel stimulus set, similar to the Tricky Triangles, and showed similar brain activations were associated with social versus random movement. Disadvantages of the Tricky Triangle stimuli include the limited number of clips available and the long length of each clip, which may be less useful for MRI paradigms and may tax attention span in younger populations. Overall, there are few well-studied paradigms available to study social attribution, and while extant methods certainly demonstrate strength,they are also limited in some aspects, especially for use in fMRI or other paradigms requiring short stimulus presentation time and a strong control task well matched for aspects such as speed of movement and proximity/collision with other shapes. Thus, designing novel stimuli to address these limitations will expand our current understanding of the neural underpinnings of social attribution across the lifespan in typical and atypical development and in a variety of neurological and psychiatric conditions. This work is of importance as this knowledge may inform the discovery of novel diagnostic measures and treatment targets in conditions characterized by social impairment.

This paper describes a novel stimulus set, the DISC, designed for use in behavioral, physiological, and neuroimaging studies of social attribution. This study reports on the baseline/normative findings of the DISC in a sample of typically developing adults. The DISC were designed to assist researchers in expanding previous research in the study of social attribution, in several ways: First, the DISC provide the ability to measure behavioral responses and contrasting brain activations using the same visual stimuli, by utilizing a cue manipulation prior to clip presentation that shifts the viewer's attention either to social or physical aspects of the scene (similar to the method of Tavares et al., 2007). Furthermore, the DISC also provide a secondary control task more similar to studies comparing socially contingent movement to random movement (Castelli et al., 2000, 2002; Gobbini et al., 2007; Ohnishi et al., 2004; Osaka et al., 2012). Thus, the DISC provide the opportunity for researchers to study both processing of inanimate movement versus social movement as well as the impact of attentional shifts on social processing using the same stimulus set. Second, the stimuli feature three shapes in each clip, which allows for the examination of the perception of multiple relationships and also provide a broad range of action types that are intended to elicit different kinds of social interpretation. Specifically, clips are characterized by three different types of social interaction (i.e., friendly approach, avoidance, aggression), as well as non-social random movement. Third, the DISC are intended to be adaptable for use in individuals with a broad range of cognitive and linguistic abilities as the specific tasks can be adapted to demand different response types, including passive viewing, forced-choice and open-ended behavioral responses, in addition to physiological or neurological responses.

With regard to behavioral findings, it was predicted that (1) participants would demonstrate engagement with the DISC task as evidenced by high accuracy in the control conditions; (2) a high proportion of participants would respond that there were "friendly" interactions depicted in clips intended to elicit friendly approach interactions (i.e. Approach DISC) and that there were "not friendly" or "non-friendly" interactions depicted in clips intended to elicit aggressive interactions or avoidance (i.e., Aggress and Avoid DISC); (3) verbal descriptions of the Approach, Aggress, and Avoid DISC would evidence greater social attribution compared to Non-social DISC; (4) social attribution as evidenced by verbal descriptions will be reduced when attention is directed towards physical compared to social aspects of the stimuli; and (5) the quality of social attributions made based on verbal descriptions would not be associated with word count or cognitive functioning.

With regard to the fMRI findings, it was predicted that (1) brain regions previously associated with animate, social contingent movement, and social attribution will be activated by the Social DISC (i.e., Approach, Aggress, and Avoid DISC) when contrasted with Non-social DISC (i.e., random movement; Castelli et al., 2000; Gobbini et al., 2007; Ohnishi et al., 2004; Osaka et al., 2012); and that (2) brain regions previously associated with processing of social versus physical aspects of similar stimuli (Ross & Olson, 2010; Schultz et al., 2003; Tavares et al., 2007; Martin & Weisberg, 2003) will be activated when attention is cued to social versus physical aspects of the Social DISC.

2. Material and method

2.1. Participants

Participants included 25 right-handed adults recruited from flyers posted at universities in the metropolitan Atlanta area. All participants provided written informed consent in accordance with the Georgia State University-Georgia Institute of Technology Joint Center for Advanced Brain Imaging (CABI) Institutional Review Board. Participants were screened for DSM-IV disorders, previous head injury, and perceptual disabilities. Two participants were excluded due to excessive movement in the scanner that could not be corrected with preprocessing and another individual was excluded due to a brain abnormality observed during the structural scan. The remaining 22 participants (9 male) were between the ages of 18 and 25 years ($M = 21.7$, $SD = 1.72$).

Average estimated intellectual skills based on the Wechsler Abbreviated Scales of Intelligence, Second Edition (WASI-II), 2-Subtest Full Scale Intelligence Quotient (FSIQ) was 109.3 ($SD = 10.66$, range = 92–129). Participants did not demonstrate clinically significant problems in the areas of Internalizing Symptoms, Inattention/Hyperactivity, Emotional Problems, or Personal Adjustment based on the Behavioral Assessment System for Children < Second Edition (BASC-2) Self Report, College Form.

2.2. Procedure

Participation took place over two sessions. During the first session, participants completed informed consent, all self-report questionnaires and measures, and a mock scan to prepare for the MRI environment. The second session took place an average of 6.64 days ($SD = 7.0$) after the first session and participants completed the experimental task during the fMRI scan and the behavioral post-task outside of the scanner. Prior to the scan, all participants underwent training on the experimental task until the participant demonstrated understanding of task demands. Participants provided responses during the experimental task with a button box held in their right hand with their pointer and middle fingers (button-finger arrangement counterbalanced).

2.3. Stimuli

The DISC is a novel stimulus set designed to study social cognition through behavioral, physiological, and neuroimaging methods. Specifically, the DISC are a set of 35 10-second animated clips created in Adobe Flash, intended to elicit social interpretation of ambiguous geometric shapes based on contingent motion cues. Each movie clip contains three geometric shapes (circle, square, triangle) that vary in color (red, blue, and yellow) in one of four scenes: a transparent box with a door that opens and closes (based on Heider & Simmel, 1944), an opaque box, a hill (based on Hamlin, Wynn, & Bloom, 2007), or an open field (Fig. 1). Clips were developed by a team of approximately seven undergraduate and graduate research assistants. Notably, many more DISC were created initially, and we used group consensus to choose which ones best depicted the intended social salience. Stimuli are available to other researchers and can be obtained by contacting the corresponding author.

2.3.1. Social DISC

Social DISC feature shapes that move in ways intended to elicit interpretations of animacy and social interaction. There are three subtypes of Social DISC ($n = 28$) based on the type of social intent: Social-Approach (Approach), Social-Aggress (Aggress), and Social-Avoid (Avoid). Approach DISC were intended to elicit interpretation of

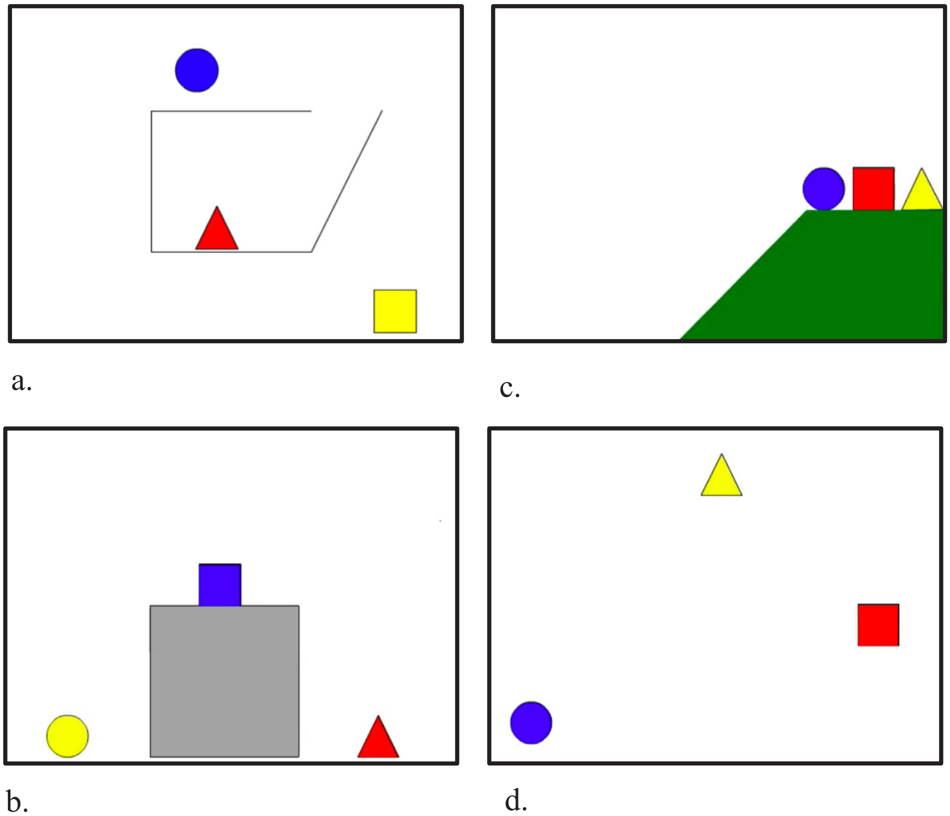

Fig. 1. The four DISC scenes transparent box with a door that opens and closes (based on Heider & Simmel, 1944; a), an opaque box (b), a hill (based on Hamlin et al., 2007; c), or an open field (d).

affiliative social motivation (e.g., helping another up a hill, dancing) and are intended to depict all three shapes as "friendly." As such, in the approach videos it was expected that participants would perceive all shapes were friends. In contrast, Aggress DISC were intended to elicit interpretation of aggressive social motivation (e.g., bullying, pushing down a hill, trapping in a box) with one shape as the aggressor towards one or two other shapes, or two shapes aggressing towards a third (i.e., at least one shape aggressed towards one other shape in all Aggress clips). As such, it was expected that participants would perceive at least two shapes as being not friends. Avoid DISC were intended to elicit interpretation of avoidant social motivation (e.g., moving away from), but without aggressive intent. Avoid clips featured either one shape avoiding one or two other shapes, two shapes avoiding a third, or all three shapes avoiding each other (i.e., at least one shape avoided at least one other shape in all Avoid clips). As such, it was expected that participants would perceive at least two shapes as being not friends.

2.3.2. Non-Social DISC

Non-social DISC feature shapes that move in ways intended to elicit inanimate and non-social interpretation. Non-social DISC ($n = 7$) were matched to the Social DISC for size, color, and props, but differ in the type of shape movement (i.e., inanimate, non-contingent, non-social movement). The shapes in Non-social DISC were intended to appear like a screen saver, with each shape moving at a similar pace in straight lines, each shape changing course only when it hits the edge of the viewing field or an aspect of the scene such as the opaque box.

2.3.3. Shape changes

A subset of Social and Non-social DISC feature shapes that independently change in size, rapidly expanding and retracting/shrinking and expanding to the original size ($n = 20$). Clips feature one ($n = 9$), two ($n = 7$), or three ($n = 4$) size changes. Size changes were random and not intended to relate to the social meaning of the scene. The size changes were incorporated into DISC in order to manipulate attention to size changes rather than social interactions among shapes, for comparison tasks.

2.4. Tasks

2.4.1. fMRI experimental task

The purpose of this task was to examine behavior and neural activation associated with processing social versus physical information in the DISC by shifting participants' attention either to the social or physical aspects of the same visual stimuli. Three block types were developed: FRIENDS, SIZE, and WATCH. FRIENDS and SIZE blocks featured Social DISC, whereas WATCH blocks featured Non-social DISC. The task included three runs, with seven blocks of each condition (i.e., FRIENDS, SIZE, WATCH) balanced across runs (order pseudorandomized; Table 1). Each block contained two DISC presentation trials with eight seconds of rest after each block (Fig. 2).

Before each DISC presentation, participants were oriented to the screen by a cross hair presented for two seconds, and then one of three cues appeared (i.e., FRIENDS, SIZE, or WATCH) for two seconds. "FRIENDS" cued clips during FRIENDS blocks, "SIZE" cued clips during SIZE blocks, and "WATCH" cued clips during WATCH blocks. After the cue, a clip was presented. After each clip, participants were provided two probes:. In the FRIENDS condition, probes included "Are any friends?," and "Are any not friends?", in the SIZE condition, probes included "Did any change size?" and "Did any not change size?", and in the WATCH condition, probes included "Push a button" and "Push the other button". Order of probe valence was counterbalanced for FRIENDS and SIZE blocks. Each probe appeared for three seconds and participants were required to respond within that time frame. It was expected that for Approach clips, participants would respond "yes" to "Are any friends?" and "no" to "Are any not friends?". For Aggress clips, it was expected that participants would respond "yes" to "Are any not

Table 1
Number of DISC movies presented within each condition during the DISC fMRI experimental task and post-task by type.

Condition	Non-Social DISC	Social DISC	Social DISC type		
			Approach	Aggress	Avoid
Experimental Task					
Friends	–	14	8	3	3
Size	–	14	2	7	5
Watch	14	–	–	–	–
Total	14	28	10	10	8
Post-Task					
Friends	–	7	5	1	1
Size	–	7	1	3	3
Watch	4	–	–	–	–
Total	4	14	6	4	4

Note. Each Non-Social DISC was presented twice during the experimental task (i.e., $N = 7$ different Non-Social DISC).

friends?" and no prediction was made about "Are any friends?" given that clips differed in the number of aggressors depicted. For Avoid clips and Non-Social DISC, it was expected that participants would respond "yes" to "Are any not friends?" and no prediction was made about "Are any friends?" given that clips differed in the number of shapes that avoided each other. Social DISC clips were not repeated during the task, but each Non-social DISC clip ($n = 7$) was presented twice during the task. Notably, similar clips were presented across the FRIENDS and SIZE blocks, but clips were preceded by a different attentional cue (i.e., FRIENDS or SIZE) to allow for examination of the effect of attention to social interactions versus physical changes within the same type of stimuli. While counterbalancing across all variables was not feasible, attempts were made to vary scene type, shape colors, number of movies featuring size changes, number of size changes, and Social DISC subtype across block types and runs.

2.4.2. Behavioral post-task

The behavioral post-task was developed to gather more behavioral information about how participants interpreted the DISC and the impact of the FRIENDS, SIZE, and WATCH cues on interpretation. The post-task was administered immediately after the fMRI scan on a 15-inch laptop computer. The post-task contained two runs (counterbalanced) containing nine DISC presentations each and order of clip presentation in each run was pseudorandomized (Table 1). The 18 DISC included in the post-task were a subset of those presented during fMRI experimental task. All participants saw the same 18 DISC during the post-task.

As in the fMRI experimental task, two-second cues (i.e., FRIENDS, SIZE, or WATCH) were presented prior to each clip. The cue preceding each DISC during the post-task was the same cue that preceded the same DISC presented during the FMRI experimental task in order to allow for direct comparison across tasks. The presentation of each DISC was followed by the prompt, "Describe the movie." The prompt remained on the screen until the participant pressed the space bar, which allowed participants as much time as needed to verbally describe the movie. Responses were voice recorded and later transcribed by trained research assistants. Participants were then provided the same probes they were presented in the scanner (i.e., two friends, size, or button press questions/prompts corresponding to the cue that proceeded clip presentation). Participants had as much time as needed to respond to all post-task probes.

The transcribed oral responses to the "Describe the movie" prompt provided a measure of mentalizing. These responses were coded using the Social Attribution Task Animation Index (AI; Klin, 2000), which was developed to quantify mentalizing in the original Social Attribution Task, from which the DISC were modeled. Each clip is scored on a 0 to 6 point scale, with 0 indicating an absence of agency and social description and 6 indicating a high level of complex social description (See Klin, 2000 for more detailed information about coding).

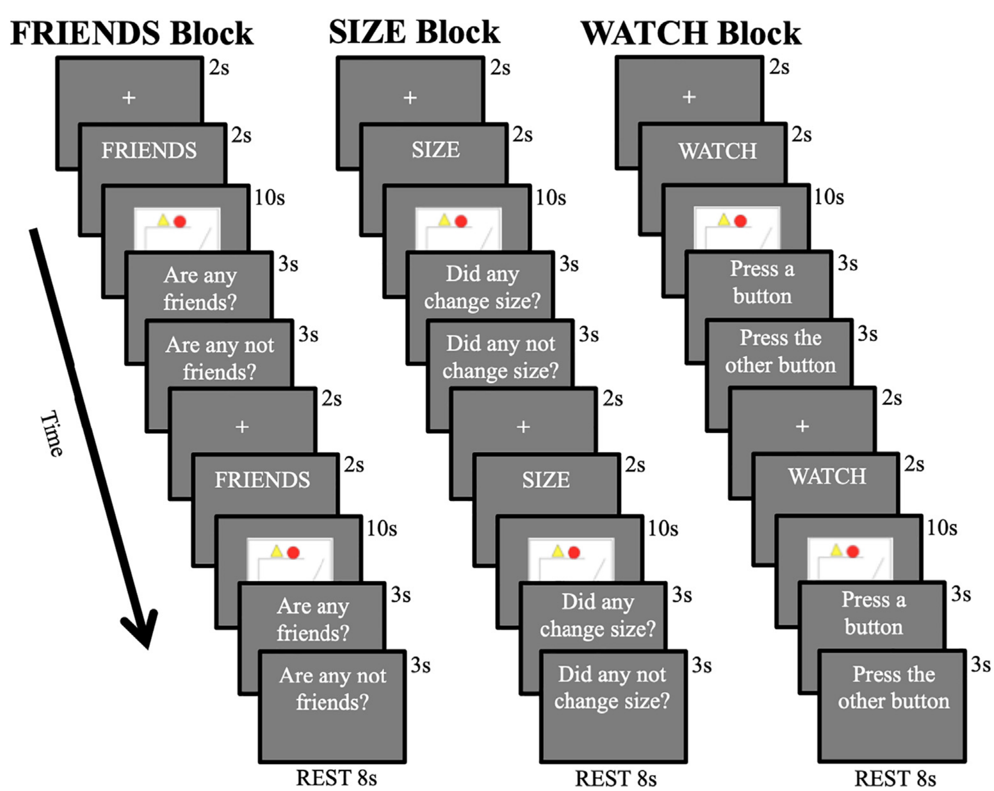

Fig. 2. DISC fMRI experimental task stimuli presentation time course for FRIENDS, SIZE, and WATCH blocks.

2.5. Image acquisition and analysis

All MRI data were collected on a Siemens 3T Trio scanner with a 12-channel RF-receive head coil. Functional images were collected using a single-shot gradient echo planar imaging sequence in the axial direction with the following scan parameters: repetition time (TR) 2130 ms, echo time (TE) 30 ms, flip angle 90°, 68 × 68 matrix, 204 × 204 mm field of view (FoV), GRAPPA parallel imaging with acceleration factor PE = 2, and isotropic voxel size of 3 mm^3. Forty axial slices collected in ascending order. A total of 330 volumes (110 in each of 3 runs) were collected for the main task. In addition, a 3D anatomical image was acquired for each participant using a T1-weighted MP-RAGE sequence at a voxel size of 1 × 1 × 1 mm with a TR of 2250 ms, TE of 3.98 ms, TI of 850 ms, 256 × 256 matrix, 256 × 256 mm FoV, 176 slices, and GRAPPA parallel imaging with acceleration factor PE = 2.

Image processing and analysis was carried out with FSL (FMRIB's Software Library, post.fmrib.ox.ac.uk/fsl). T1-weighted images were brain-extracted and bias-corrected. Alignment to the MNI152 template was accomplished via an initial 12-dof affine registration using FLIRT (Jenkinson and Smith, 2001, Jenkinson, Bannister, Brady, & Smith, 2002) followed by a nonlinear warp using FNIRT (Andersson, Jenkinson, & Smith, 2010). BOLD images were subjected to motion correction, identification of motion outliers, and rigid-body 6-dof linear alignment to subjects' T1-weighted images. fMRI analysis was accomplished using FEAT (FMRI Expert Analysis Tool) Version 5.98. The first two volumes of each run were discarded prior to analysis. BOLD activation was modeled using multiple linear regression. Head movements were included as regressors of no interest. Task-related activation was modeled in 10-second blocks for the cartoon animations cued by "FRIENDS," "SIZE," and "WATCH." Additionally, these cues themselves were modeled in 2-second blocks, and subjects' responses were modeled in 3-second blocks. Time-series statistical analysis was carried out using FILM with local autocorrelation correction (Woolrich, Ripley, Brady, & Smith, 2001). Z statistic images were thresholded using clusters determined by $Z > 2.3$ and a corrected cluster significance threshold of $p = 0.05$ (Woolrich et al., 2001). Higher-level analysis was carried out using a fixed effects model, by forcing the random effects variance to zero in FLAME (FMRIB's Local Analysis of Mixed Effects; Woolrich, Behrens, Beckmann, Jenkinson, & Smith, 2004). Each subject's significant activations for the FRIENDS > SIZE and FRIENDS > WATCH contrasts were then subjected to a Monte Carlo permutation test using FSL's randomise tool (Winkler, Ridgway, Webster, Smith, & Nichols, 2014). One-sample t-tests were used to find significant activations for these contrasts at the group level. Results images were thresholded at $p < .05$ after family-wise error correction using threshold-free cluster enhancement (Smith & Nichols, 2009). FSL's *cluster* and *atlasquery* tools were used to obtain the size and location of significant activations.

3. Results

3.1. Behavioral data

3.1.1. Do participants engage with the task as evidenced by high accuracy in the control conditions?

As a check that participants were attending to the instructions and to demonstrate engagement, accuracy of responses during the control conditions was computed (i.e., WATCH and SIZE conditions). During the DISC fMRI experimental task, participants accurately pressed alternate buttons within each presentation trial 99.8% of the time during the WATCH condition. During the post-task, participants were 100% accurate in pressing alternate buttons during the WATCH condition. Size accuracy scores were computed for each participant by computing the proportion of correct responses during SIZE blocks to "Did any change size?" and "Did any not change size?" during the DISC fMRI experimental task and post-task. Response rate during the DISC fMRI experimental task was 96.9% and mean proportion correct was 0.899 ($SD = 0.079$). There was no difference in the proportion correct for "Did any change size?" ($M = 0.902$, $SD = 0.092$) and "Did any not change size?" ($M = 0.896$, $SD = 0.112$), $t(21) = 0.216$, $p = .831$, $d = 0.06$. Mean proportion correct during the behavioral post-task was 0.896 ($SD = 0.154$) and there was no difference in the proportion correct for "Did any change size?" ($M = 0.896$, $SD = 0.141$) and "Did any not change size?" ($M = 0.896$, $SD = 0.172$), $t(21) = 0.000$, $p = 1.0$, $d = 0.00$. There was no difference in the mean proportion correct across the fMRI experimental task ($M = 0.899$, $SD = 0.079$) and post-task ($M = 0.896$, $SD = 0.141$), $t(21) = 0.100$, $p = .922$, $d = 0.03$.

3.1.2. Do participants perceive that there are "friendly" interactions depicted in the Approach DISC and that there are "non-friendly" interactions depicted in the Aggress and Avoid DISC?

Because the study aim examines social interpretation of ambiguous stimuli, there is no "correct" social interpretation; however there is an expected social interpretation. Specifically, for the Approach DISC it was expected that participants would perceive all shapes as friends.In contrast, the Aggress DISC were intended to elicit interpretation of aggressive social motivation (e.g., bullying, pushing down a hill, trapping in a box) with at least one shape aggressing towards at least one other shape. As such, it was expected that participants would perceive at least two shapes as being not friends. Avoid DISC were intended to elicit interpretation of avoidant social motivation (e.g., moving away from), but without aggressive intent, and clips featured at least one shape avoiding at least one other shape. As such, it was expected that participants would perceive at least two shapes as being not friends. Conformance to these "expected" responses was examined. Specifically, the proportions of "yes" responses to probes during the DISC fMRI experimental task and post-task as well as the quality of the social descriptions during the post-task were examined to determine whether participants made expected social interpretations.

Proportions of "yes" responses to probes during the DISC fMRI experimental task and the post-task were examined (Table 2). Participants responded to 96.9% of trials during the DISC fMRI experimental task and 100% of trials during the post-task. As expected, results suggest that participants typically perceived at least one "friendly" relationship when viewing Approach DISC and that few people perceived there to be at least one non-friendly relationship. Furthermore, participants typically perceived at least one "non-friendly" relationship while viewing the Aggress DISC. Interestingly, participants also typically interpreted at least one "friendly" relationship while viewing the Aggress DISC. Similarly, results from the Avoid DISC show that participants typically interpreted at least one "non-friendly" relationship and at least one "friendly" relationship. Two repeated measures ANOVAs were conducted in order to examine the consistency of mean forced-choice responses to "Are any Friends?" and "Are any not friends?" probes within

Table 2
Mean proportion of "Yes" probe responses, standard deviations by social DISC subtype during the DISC fMRI experimental task and post-task.

Social DISC subtype	Question "Are any friends?" *M (SD)*	"Are any not friends?" *M(SD)*	Cohen's d
Experimental task			
Approach	0.909 (0.149)	0.260 (0.171)	4.04*
Aggress	0.942 (0.176)	0.942 (0.143)	0
Avoid	0.985 (0.071)	0.909 (0.234)	0.44
Post-Task			
Approach	0.918 (0.147)	0.246 (0.174)	4.17*
Aggress	0.952 (0.218)	0.952 (0.218)	0
Avoid	0.952 (0.218)	0.902 (0.235)	0.23

Note. Response of "Yes" = 1. *$p < .001$.

the FRIENDS condition of DISC presented both in the scanner and during the post-task; there was no effect of task for either analysis, $F_{\text{Friends}}(1, 21) = 0.140$, p = .712; $F_{\text{Not Friends}}(1, 21) = 0.251$; $p = .621$.

3.1.3. Do verbal descriptions of the Approach, Aggress, and Avoid DISC during the post-task evidence greater social attribution compared to Non-social DISC? Is the level of social attribution based on verbal descriptions associated with word count or cognitive functioning?

Two trained coders assigned a score from the AI to each oral narrative for every participant (18 total for each participant). Inter-rater reliability for the coders was very good (intraclass coefficient = 0.937, CI = 0.923–0.948). Example descriptions of Social DISC stimuli include “Two pieces are kinda together with friends. They try to bully another, take its money or whatever, and eventually the piece in the middle leaves” and “The children were playing with something and the mother reprimanded them.” However, Non-Social DISC (i.e., featuring random movements) elicited descriptions such as, “Everything was the same, nothing changed. Monotonous, kinda boring” and “The circle and the square and the triangle are just free-floating.” The average AI score was computed for each oral narrative for every participant from the two AI codes provided by the coders. AI codes and word counts were averaged across stimulus type (Table 3). Word count did not correlate with animacy codes for 16 of the 18 movies presented (*r*s range from −0.069 to 0.402). The two clips with significant correlations included one Non-social DISC ($r = 0.588$, $p = .004$) and one Avoid DISC ($r = 0.728$, $p < .00$). Both clips featured an open field and no size changes. These two clips had the lowest mean word counts out of all the movies included in the post-task. Notably, these two clips tended to elicit very short descriptions (i.e., lowest mean word counts out of all DISC presented in the post task) and had a limited range of AI (i.e., AI codes ranged from 0 to 3). As such, the limited word count and range may have contributed to an anomalous relationship between these variables for these two clips.

Results from a repeated measures ANOVA examining average AI codes across the four DISC subtypes during the post-task showed that AI scores differ across stimulus type, $F(3, 63) = 38.66$, $p < .001$, partial $\eta^2 = 0.648$. As expected, pairwise comparisons indicated Non-social DISC AI codes were significantly lower than all other DISC types (*ps* < 0.001). AI codes associated with Avoid clips were lower than Aggress clips ($p = .052$) and Approach codes ($p < .001$). Aggress and Approach codes were highest rated and were not different from each other ($p = 1.00$). AI codes within Social DISC subtypes and Non-social DISC were not correlated with estimated FSIQ (*r*s range from −0.379 to 0.197), or scores on the WASI-II Vocabulary (*r*s range from −0.316 to 0.305) or Matrix Reasoning subtests (*r*s range from −0.101 to −0.68; all *ps* > 0.08).

Table 3
Means, standard deviations, and ranges of average adapted AI scores and word counts computed from verbal descriptions and SAM valence and arousal ratings for each non-social DISC and social DISC subtypes during the post-task.

DISC subtype/condition	AI *M*(*SD*) range	WC *M*(*SD*) range
Approach subtype	2.0 (0.678) 0.67–3.83	34.3 (17.3) 8.7–74.5
Aggress subtype	1.90 (0.676) 0.38–3.38	36.1 (17.9) 7.0–68.0
Avoid subtype	1.47 (0.633) 0.40–3.20	34.3 (16.4) 12.0–59.5
Non-social subtype/watch condition	0.739 (0.586) 0–2.75	24.7 (12.2) 11.3–60.0
Social condition	2.18 (0.751) 0.94–3.88	–
Size condition	1.47(0.659) 0.0–3.0	–

Note. AI = Animacy Index; WC = Word Count. Valence: 1 = Very Positive, 5 = Neutral, 9 = Very Negative; Arousal: 1 = Very Intense, 5 = Moderate, 9 = Very Mild.

3.1.4. Is social attribution, as evidenced by verbal descriptions, reduced when attention is directed towards physical compared to social aspects of the DISC?

Results from a repeated measures ANOVA comparing average AI scores across the three conditions in the post-task (i.e., when cued to SIZE, FRIENDS, or WATCH) indicated significant differences in mean AI scores across all three conditions, $F(2, 42) = 41.97$, $p < .001$, partial $\eta^2 = 0.666$. As expected, pairwise comparisons with a Bonferroni correction indicated mean AI scores for the FRIENDS condition were greater than the SIZE condition and mean AI scores for the FRIENDS and SIZE conditions were greater than the WATCH condition. Given that there were a disproportionately low number of Avoid clips in the FRIENDS condition compared to the SIZE condition , subsequent analyses were conducted to examine mean AI scores for the FRIENDS and SIZE conditions including only the Approach and Aggress clips to determine whether the dearth of Avoid clips in the FRIENDS condition may have driven this difference. A paired samples *t*-test including only Approach and Aggress DISC indicated mean AI scores remained significantly higher for the FRIENDS ($M = 2.17$) compared to the SIZE condition ($M = 1.78$), $t(21) = 2.20$, $p = .039$, $r^2 = 0.12$.

3.2. fMRI data

3.2.1. Are brain regions previously associated with animacy and socially contingent movement activated by the social DISC when compared to random movement (i.e., FRIENDS > WATCH)?

To match the comparisons made in previous fMRI studies using control tasks featuring random movement (Castelli et al., 2000, 2002; Gobbini et al., 2007; Martin & Weisberg, 2003; Ohnishi et al., 2004; Osaka et al., 2012), we examined whole brain activation differences between the FRIENDS condition and the WATCH (i.e., random) condition (Fig. 3, Table 4). Activations comprised a distributed network including large regions of inferior frontal, occipitotemporal, and parietal regions, which were highly overlapping with previous studies. Specifically, activation occurred in DMPFC, IFG, frontal operculum, premotor cortex, medial occipital cortex, lateral occipitotemporal cortex including the STS, anterior inferior temporal cortex and TPs, FG, IPC, precuneus, thalamus, and cerebellum.

3.2.2. Will brain regions previously associated with attentional focus on social versus physical aspects of similar stimuli be activated when participants are cued to attend to social versus physical aspects of the Social DISC (i.e., FRIENDS > SIZE)?

The contrast between videos cued for social versus physical attention (Fig. 3, Table 5) revealed similar activation to the FRIENDS > WATCH contrast, with more extensive activation in several regions including DMPFC and VMPFC, IFG, precuneus, and TP. Conversely, for this contrast, activation was less extensive in occipitotemporal cortex, premotor cortex, and IPC.

4. Discussion

The purpose of this study was to present a novel stimulus set designed to study social attribution and to report on the initial behavioral and fMRI findings of the DISC in a sample of typically developing adults. The DISC were designed to assist researchers in expanding previous research by providing a stimulus set with a large number of stimuli featuring various movement types intended to elicit different types of social interpretation, that are adaptable for use in individuals across the lifespan with a broad range of abilities given the versatility of use in a variety of experimental methods, including fMRI.

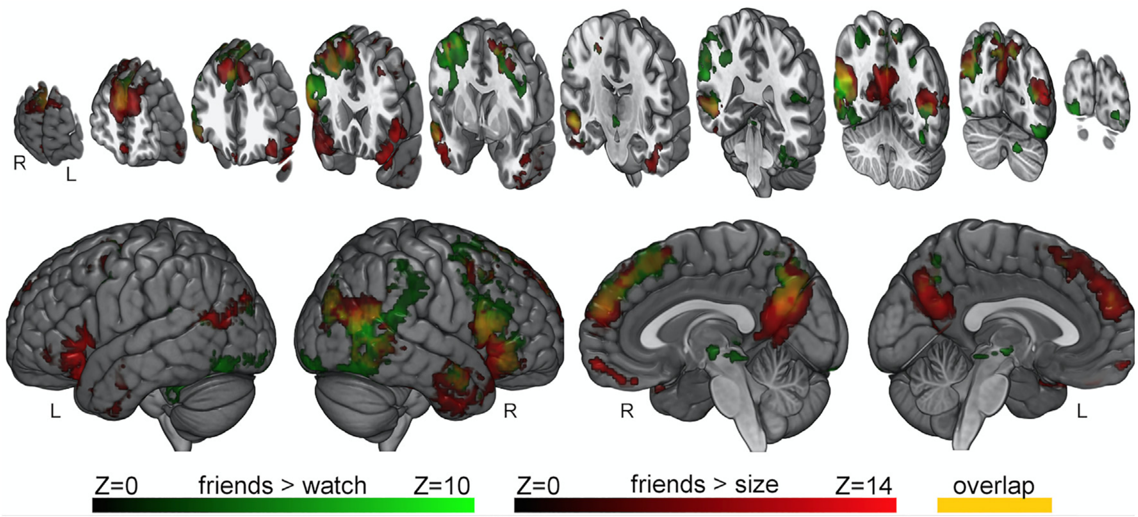

Fig. 3. Activation for the FRIENDS > WATCH and FRIENDS > SIZE contrasts. Images are displayed on the MNI152 T1 template using MRIcroGL. In the top row, coordinates of coronal slices are y = −92, −73, −54, −35, −16, 3, 22, 41, and 60, respectively.

4.1. Behavioral findings

With regard to task engagement, participants were generally accurate during the fMRI experimental task and post-task control conditions as evidenced by high accuracy during both the WATCH and SIZE conditions. Furthermore, forced-choice responses during the FRIENDS condition reflected expected responses for all three Social DISC types. Taken together, it appears that participants were engaged with task demands, which supports further interpretation of the results. Given that the DISC appear highly engaging, these data also illustrate the potential utility of the DISC in future studies of individuals with limitations in task engagement such as in children and older adults or those with conditions impacting task vigilance.

Forced-choice responses and verbal descriptions of the stimuli were examined across DISC types to better understand the presence and sophistication of social attributions made to the DISC. As expected, verbal descriptions of the Approach, Aggress, and Avoid DISC evidenced greater social attribution compared to Non-social DISC and descriptions of the Avoid DISC demonstrated lower levels of social attribution than the Approach and Aggress DISC. These findings confirm that participant's interpretations of the social intent of the DISC were grossly achieved. Forced-choice from probes in the scanner and during the post-task data also generally support predictions about social interpretations. Participants generally perceived at least one "friendly" relationship in Approach clips and at least one "non-friendly" relationship in the Aggress and Avoid clips while in the scannerand during the post-task. Also as expected, a very low proportion of participants responded that there was a "non-friendly" relationship featured in the Approach clips, indicating that most participants interpreted all three shapes to be friends. This makes sense, as these clips did not necessarily attempt to portray only two shapes as friendly to one another, but all three. Interestingly, participants typically interpreted at least one "friendly" relationship in the Aggress and Avoid clips. While this was not the primary intent, it is possible that participants viewed two shapes that were not aggressive as aligned against an aggressor at least in some of the clips, which is consistent with childhood bullying literature

Table 4
Significant clusters in the friends > watch contrast.

			Coordinates of Max Z			Coordinates of Center of Gravity			
Cluster	Voxels	Max Z	x	Post	z	x	Post	z	Anatomical location(s)
1	7373	13.4	20	34	42	20	38.6	41.7	Right middle temporal gyrus (posterior and temporo-occipital divisions), inferior temporal gyrus (temporo-occipital division), superior parietal lobule, anterior and posterior supramarginal gyrus, angular gyrus, superior and inferior lateral occipital cortex, fusiform gyrus (temporo-occipital division)
2	6788	11.2	18	73	45	28.2	72.2	52.6	Right frontal pole, superior frontal gyrus, middle frontal gyrus, inferior frontal gyrus pars triangularis and pars opercularis, precentral gyrus, frontal orbital cortex
3	1970	10.1	66	37	27	66.2	31.2	32.8	Left middle and inferior temporal gyri (temporo-occipital division), fusiform gyrus (posterior temporal, temporo-occipital, and occipital divisions), superior and inferior lateral occipital cortex
4	972	7.38	40	27	57	43.9	30.1	56.9	Bilateral precuneus, cuneus, superior lateral occipital cortex, superior parietal lobule
5	723	7.27	56	59	64	60.7	62	61.3	Left superior frontal gyrus, middle frontal gyrus, precentral gyrus
6	297	9.52	32	17	27	31.3	16.5	29.3	Right inferior lateral occipital cortex, occipital furiform gyrus, occipital pole
7	165	6.59	39	48	33	41.1	47.9	32.2	Right postero-lateral thalamus, superior and inferior colliculus
8	142	8.9	55	14	27	57.6	15	30.8	Left occipital pole, inferior lateral occipital cortex
9	137	5.67	64	38	59	62.4	38.2	56.8	Left superior parietal lobule, anterior and posterior supramarginal gyrus, angular gyrus, superior lateral occipital cortex
10	135	8.28	73	42	46	71.1	43	46.6	Left parietal operculum, planum temporale, posterior supramarginal gyrus
11	69	7.75	46	55	33	43.1	56.2	33.8	Right thalamus, bilateral midbrain
12	43	6.28	55	25	19	53.3	26.2	19	Left cerebellum
13	28	3.17	23	83	52	21.8	80	53	Right frontal pole, middle frontal gyrus
14	20	5.37	20	71	18	21	68.6	18.7	Right temporal pole, anterior middle temporal gyrus

Table 5
Significant clusters in the friends > size contrast.

Cluster	Voxels	Max Z	Coordinates of Max Z			Coordinates of Center of Gravity			Anatomical location(s)
			x	Post	z	x	Post	z	
1	7724	9.76	22	34	43	19.8	50.3	35.1	Right frontal orbital cortex, inferior frontal gyrus pars triangularis and opercularis, angular gyrus, middle and inferior temporal gyri (anterior, temporo-occipital, & posterior divisions), superior & inferior lateral occipital cortex
2	6696	8.19	42	90	48	41.5	80.1	56.6	Bilateral frontal pole, superior frontal gyrus, middle frontal gyrus, paracingulate gyrus
3	3052	10.1	43	33	49	43	31.4	49.4	Bilateral intracalcarine cortex, supracalcarine cortex, cuneus, precuneus, posterior cingulate gyrus, posterior cingulate gyrus, superior lateral occipital cortex
4	1727	9.75	69	28	44	68.3	29.7	45.2	Left middle temporal gyrus (temporo-occipital part), posterior supramarginal gyrus, angular gyrus, superior and inferior lateral occipital cortex
5	1492	9.18	67	79	33	67.1	75.6	31	Left temporal pole, inferior frontal gyrus pars opercularis and triangularis, frontal orbital cortex, frontal operculum cortex, frontal pole
6	941	7.04	74	62	22	70	59.9	21.2	Left middle and inferior temporal gyri (anterior division), fusiform gyrus (anterior temporal division), temporal pole
7	135	7.54	44	94	29	44	90	26.7	Bilateral medial frontal pole

suggesting that victims tend to be friends with other victims (Champion, Vernberg, & Shipman, 2003; Pellegrini, Bartini, & Brooks, 1999). Additionally, two shapes aggressing towards a third may also have been perceived as aligned. Similarly, two shapes avoiding a third, or two shapes being avoided by a third may have also been perceived as aligned. Given that similar stimulus sets have typically only featured two shapes (Abell et al., 2000; Tavares et al., 2007), previous studies of social attribution have yet to examine perceptions of more complex social relationships that may emerge when more than two shapes are presented.

Future research should examine other social factors of the DISC independent of attentional cues and the potential impact of these attentional cues on social interpretations utilizing a post-task including more DISC within each subtype. The increased social complexity of this task opens the door to additional future research investigating perception of social interactions within a group.

4.2. Neuroimaging findings

Some may argue that the most finely controlled comparison of activations associated with social attribution utilizes the same visual stimuli with a different attentional cue (i.e., FRIENDS > SIZE). However, we developed an additional and alternate comparison (i.e., FRIENDS > WATCH) in the case that the attentional cue was not enough to preclude social interpretation as well as to be able to compare current findings to extant literature using more "random-like" control task. Furthermore, this additional comparison enables investigators to disambiguate the separate and interacting effects of pre-attentional social processing (i.e., activations/perception of social stimuli when attention is focused on a physical characteristic; SIZE condition) and social attention (i.e., FRIENDS condition). A strength of the DISC paradigm employed is being able to conduct both complementary comparisons. Compared to Non-social DISC, activations for the Social DISC (i.e., FRIENDS condition only; FRIENDS > WATCH) were consistent with previous literature examining similar comparisons of random movement and social contingent movement in the context of social attribution. These areas, including the DMPFC (Castelli et al., 2000; Martin & Weisberg, 2003; Ohnishi et al., 2004), IFG (Gobbini et al., 2007; Osaka et al., 2012), TPJ/STS (Castelli et al., 2000; Ohnishi et al., 2004; Tavares et al., 2007), inferior temporal gyrus (Gobbini et al., 2007; Osaka et al., 2012), FG (Castelli et al., 2000; Gobbini et al., 2007; Martin & Weisberg, 2003; Ohnishi et al., 2004; Tavares et al., 2007), TP, (Castelli et al., 2000; Ohnishi et al., 2004; Osaka et al., 2012), and precuneus (Gobbini et al., 2007), are commonly associated with social brain areas implicated in the detection of animacy, socially contingent movement, and mental state attribution. Notably, we also observed premotor (also observed by Osaka et al., 2012) and inferior parietal lobule activations (also observed by Gobbini et al., 2007), which are consistent with literature implicating these areas in processing goal directed actions of agents regardless of form (Stosic, Brass, Van Hoeck, Ma, & Van Overwalle, 2014). The social interpretation of these activations is further supported by behavioral results indicating greater AI scores, reflective of more complex social interpretation, for Social DISC versus Non-social DISC. This contrast also yielded activations in the intraparietal sulcus and EC (also observed by Castelli et al., 2000; Ohnishi et al., 2004), which are associated with attentive tracking of moving targets (Culham et al., 1998) and higher order visual processing, respectively, which is consistent with the differential movement and task demands of the Social DISC compared to Non-social DISC.

When attention was cued to the social versus physical aspects of Social DISC (i.e., FRIENDS > SIZE), activations emerged that were overlapping with a previous study utilizing a similar manipulation (i.e., similar stimuli presented with a different attention cue) featuring two interacting shapes (e.g., DMPFC, TPJ/STS, and TP ;Tavares et al., 2007). Notably, this contrast demonstrated attenuated activation in earlier, perceptually-driven regions associated with form and motion processing (e.g., EC, IPC, premotor cortex) and increased activation in higher-order regions associated with social processing, self-referential processing, and social decision making (e.g., VMPFC, DMPFC, precuneus, TP). This likely reflects increased attention to physical, concretely perceptible aspects of the stimuli in the SIZE condition and processing of inferred intentional and emotional states in the FRIENDS condition. These data corroborate previous research that activation in these areas is sensitive to top-down attentional influence to the social features versus the physical features of similar stimuli. Importantly, these findings support that the SIZE cue was an adequate manipulation to shift attention away from social features of the stimuli to physical aspects of the DISC, to the extent that attenuated social brain activations were observed. This is consistent with behavioral findings from the post-task, which demonstrated an attenuation of social attribution as demonstrated by reduced AI codes based on verbal descriptions of Social DISC preceded by a SIZE cue versus a FRIENDS cue. Importantly, the fact that activations, as well as social descriptions, were attenuated and not eliminated suggests that some degree of social processing is automatic. This is consistent with previous research demonstrating humans automatically make social attributions without overt attentional focus as evidenced by electroencephalogram oscillations (Duan, Yang, He, Shao, & Yin, 2018).

Notably, activations in the amygdala were not observed in the FRIENDS > SIZE contrast or in the FRIENDS > WATCH contrast, which is contrary to findings from similar studies (Martin & Weisberg, 2003; Ross & Olson, 2010; Schultz et al., 2003; Tavares et al., 2007). One possible explanation for the lack of amygdala activation could be that our stimuli may not elicit enough emotional arousal, or at least sustained arousal, required for amygdala activation. This was developed as an advantage for certain study designs requiring short stimulus exposure times, but may limit the degree of sustained emotional arousal that may be required for amygdala activation, or the relatively benign level of arousal compared to previous studies demonstrating robust amygdala response to more fearful or highly arousing stimuli. Future research is warranted to better understand the involvement of the amygdala in different versions of SAT type tasks.

Interestingly, some areas of activation associated with social processing (i.e., fusiform, premotor) present in the FRIENDS > WATCH contrast, were not present in the FRIENDS > SIZE contrast. This may be due to the robust effect of the specific features of the stimuli on bottom-up processing that cannot be attenuated by top-down attentional shifts elicited by the SIZE cue, particularly for the FG, which was activated in previous studies including similar contrasts. Notably, activation in the intraparietal sulcus during the FRIENDS > WATCH contrast was no longer significant in the FRIENDS > SIZE contrast; however this was expected since attending to social features and physical features both require careful attention to moving targets, whereas the WATCH condition was a more passive task (Culham et al., 1998).

There were also several social brain areas that appeared more extensive during the FRIENDS > SIZE than in the FRIENDS > WATCH contrast including the inferior frontal, TP, and TPJ/STS, and one new area of activity, the VMPFC. Recent research suggests that the VMPFC is implicated in attention to socially relevant information (Wolf, Philippi, Motzkin, Baskaya, & Koenigs, 2014). Thus, even though participants were not explicitly cued to process social or physical aspects of the Non-social DISC during the WATCH condition, they may have attempted to make sense of the random motion within social context (i.e., attending to movements, deciding whether these movements have social meaning); however, when engaged in an active task (i.e., looking for size changes) during the SIZE condition, these processes were attenuated. Future research may be conducted to examine the extent of social processing that may occur during the Non-social DISC.

While the DISC were developed to overcome limitations of previous mentalizing and social attribution stimuli, there are some limitations of the DISC. First, the short duration of the DISC make this stimulus set ideal for certain paradigms such as MRI; however, this may limit the intensity or complexity of interactions depicted the DISC. Second, the DISC were developed based on scripted social scenes that the experimenters generated and clips were spontaneously developed in Adobe Flash. As such, differential results may emerge if naturalistic stimuli were directly converted into the clips. Third, while including three shapes in each DISC may be an advantage in studying complex social relationships, it also may limit the neural activations and perceptual ratings when comparing the different subtypes of Social DISC given the multiple relationships among the shapes and future research is warranted to better understand how these complex relationships are interpreted. Fourth, the aim of the current study was to examine the DISC for use in typical adult populations; however, future research is needed to examine the DISC in a broader age range and whether the DISC have utility of detecting disruptions in social cognition in clinical samples.

Furthermore, while efforts were made to balance the variables of the stimuli including Social DISC type, scene, shape colors, size changes etc., counterbalancing these variables in the fMRI experimental task and post-task were not feasible. As such, there were a disproportionately low number of Avoid DISC presented during the FRIENDS compared to SIZE condition during the fMRI experimental task. Given that the FRIENDS > SIZE contrast indicated findings similar to previous studies examining similar contrasts, it is not expected that activations would be considerably different if the number of Avoid DISC was more balanced across conditions; however, this should be considered a limitation and future research should examine neural activations associated with the different Social DISC subtypes.

Future research should examine potential differences in brain activations across the different social DISC subtypes (i.e., approach, aggress, avoid), and to examine individual properties of each stimulus, both of which were beyond the scope of this initial study given the study manipulation (i.e., SIZE vs. FRIENDS). Researchers should also utilize the DISC to examine individual differences in behavioral and neuroimaging responses and the development of mentalizing, specifically social attribution, given that the stimuli can be applied to a broad age range. Future directions should evaluate how children and adolescents perceived these stimuli. Furthermore, the DISC should be utilized to examine differences in behavioral responses and neuroimaging findings in clinical populations and how performance may predict or measure responses to intervention. Our own research has utilized this paradigm to demonstrate changes in neural activation during social perception in a double-blind oxytocin study with women (Hecht et al., 2017).

5. Conclusion

The DISC is a novel stimulus set developed to examine social attribution and provides researchers with the flexibility to use the same stimulus set to study social attribution using different measurement techniques and clinical populations. This study provides behavioral and fMRI data supporting that typically developing adult participants anthropomorphize the stimuli and that the social intent of the clips were perceived as intended. Neuroimaging findings show that contrasts utilizing two control tasks yield activations in areas consistent with previous research identifying areas associated with processing animacy and mentalizing. Results lend empirical support for the use of the DISC in future studies of social cognition.

Disclosures

Diana L. Robins is co-owner of M-CHAT, LLC, which licenses use of our screening tool for commercial products. She also sits on the advisory board for Quadrant Biosciences, Inc.

CRediT authorship contribution statement

Natasha N. Ludwig: Conceptualization, Methodology, Software, Formal analysis, Investigation, Writing - original draft, Project administration, Funding acquisition, Supervision. **Erin E. Hecht:** Writing - original draft, Formal analysis. **Tricia Z. King:** Writing - review & editing. **Kate Pirog Revill:** Formal analysis, Writing - review & editing. **Makeda Moore:** Data curation, Writing - review & editing. **Sarah E. Fink:** Data curation, Writing - review & editing. **Diana L. Robins:** Conceptualization, Methodology, Resources, Writing - review & editing, Supervision, Funding acquisition.

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Appendix A. Supplementary material

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