Spring 4-7-2017

Reaching-to-grasp my intention: Relating communication skill with social action

Jennifer A. Cooper
jcoope73@uwo.ca

Reaching-to-grasp my intention: Relating communication skill with social action

Jennifer A. Cooper

Honors Psychology Thesis
Department of Psychology
Western University
London, Ontario, CANADA
April 2017

Thesis Advisors: Kaitlin Laidlaw, Ph.D. & Jody Culham, Ph.D.

Abstract

The present study investigated whether social aptitude is related to the effects of social intention on reach-to-grasp actions. Reach-to-grasp actions performed with social intentions (e.g. reaching to pick up a coffee cup to give to a friend) are characterized by different kinematic patterns than those performed with nonsocial intentions (e.g. reaching to pick up a coffee cup to move it aside). These intention-based kinematic changes are thought to serve a communicative function, allowing co-actors to better predict and respond to actions that are relevant to them. If this is true, then individuals who rate themselves as strong communicators should show better discrimination between social and nonsocial actions, whereas those who have poor communication skills should perform actions that are not as clearly differentiated based on social intentionality. In the present study, participants picked up and moved a block to the center of the table to either be collected by another person (social Give condition), or not (nonsocial Place condition). Although the required motor sequence was the same in both conditions, results indicate that actions with social (Give) intentions were associated with different kinematic patterns than actions with nonsocial (Place) intentions. Further, the degree to which certain action kinematics differed based on social intentionality was correlated with participants' self-reported communication skills. The results are discussed in terms of how social interactions may benefit from communicating social intentionality through action. Future directions for extending beyond the conclusions of the present findings will also be discussed.

Reaching-to-grasp my intention: Relating communication skill with social action

Humans, as highly social animals, have evolved to effectivity communicate through both spoken language and nonverbal social cues (Mateas and Sengers, 1999). Our social cognitive processes enable us to infer beyond observable behaviours to understand the minds of others (Jacob & Jeannerod, 2005). This ability is crucial to thrive in complex human social interactions (Adolphs, 2009; Krach, Paulus, Bodden & Kircher, 2010). When interacting with conspecifics, we interpret their mental states and make predictions about the future course of their actions in order to adapt our own behaviour and respond appropriately (Hamilton & Grafton, 2007; Lewkowicz, Quesque, Coello, & Delevoye-Turrell, 2015). For instance, is your co-worker getting the water pitcher to pour himself a glass of water or is he passing it to you? To readily produce the appropriate response (i.e. the motor response required to accept the glass), we must be able to predict the intention of the actor early in the action.

It is clear that nonverbal cues convey information about one's inner state and intentions. However, there is controversy concerning the ability to understand others' intentions through the observation of reach-to-grasp actions (e.g., Jacob, 2008; Jacob & Jeannerod, 2005; Kilner, Friston & Firth, 2007). Growing evidence suggests that intentions translate into distinctive motor patterns (i.e. grasping kinematics; Ansuini, Begliomini, Ferrari, & Castiello, 2010; Becchio, Sartori, & Bulgheroni, 2008a; Becchio, Sartori, Bulgheroni, & Castiello, 2008b; Ferri, Campione, Dalla Volta, Gianello, & Gentilucci, 2010; Quesque, Lewkowicz, Delevoye-Turrell & Coello, 2013; Quesque, Delevoye-Turrell, & Coello, 2016; Sartori, Becchio, Bara, & Castiello, 2009), allowing observers to detect these kinematic differences and implicitly use this motor information to predict the future course of the action (Manera, Becchio, Cavallo, Sartori & Castiello, 2011; Sartori, Becchio, & Castiello, 2011). In the example above where the co-worker either passes or pours the water, there would be subtle differences in the movements during the initial reach to pick up the pitcher. Are these differences implicitly implemented to signal others to prepare for a response? Or is it the task demands that produce these kinematic differences? In other words, the initial acts of picking up the glass are identical, though the motor demands of the sequential task (pour vs. pass) are different. If the motor demands of a task are equated, would there still be kinematic differences in the initial action? The first aim of the present study is to measure the differences in reach-to-grasp kinematics of actions performed with social (Give condition) and nonsocial (Place condition) intentions. Further, to gain insight into whether social kinematic differences serve a communicative function (i.e. allowing co-actors to better predict and respond to actions that are directed toward them), the second aim of the study is to determine whether the degree of kinematic differences across social (Give) actions and nonsocial (Place) actions are correlated with self-reported measures of social and communication skills.

Intentionality in Action

The act of an individual reaching toward and grasping a pitcher can be understood from at least three different levels. The intention level describes why the action is being performed (the pitcher may be picked up with the intention to pour, refill, or pass it to a co-worker). The physical goal level defines the direct goal of the initial motor act, to reach out, grasp, and pick up the apple. Lastly, the motor kinematic level describes the motion of the movement through space and time, as well as the muscle activity that contributes to the execution of the action (e.g. the movement trajectory, velocity, grip aperture; Hamilton & Grafton, 2007). While it is obvious that physical goals shape kinematics, there is evidence that intentions influence the kinematics of earlier actions (i.e. reach-to-grasp actions) within a larger action sequence (Ansuini, Santello, Massacessi, Castiello, 2006, Armbrüster & Spijkers, 2006; Sartori, Straulino, Castiello, 2011).

Thus, although it is clear kinematics reflect motor intentions, the issue currently under debate is whether motor information at the kinematic level can be used to communicate and understand higher-order intentions (Jacob & Jeannerod, 2005; Jacob, 2008; Kilner et al., 2007).

Early evidence of this intention-related kinematic changes was found by comparing reach-to-grasp action kinematics when individuals picked up the same object to be either thrown into a large container, or placed into a small container (Marteniuk, MacKenzie, Jeannerod, Athenes & Dugas, 1987). The authors reported that the initial phase of the action (i.e. reach and grasp action) was performed slower when the object was picked up with the intention to place it in a small container versus when it was to be thrown. Moreover, Ansuini, Giosa, Turella, Altoè and Castiello (2008) explored this by investigating the shaping of the hand when individuals reached toward and grasped a water bottle to perform different tasks (i.e. throw, reposition, pass to partner, pour to container, no subsequent action). Though the initial action goal remained consistent across conditions (i.e. picking up the bottle), the overall intention guiding the action sequence affected the finger placements (i.e. shaping of the hand) during the reach-to-grasp phase, as well as the duration. For example, when the bottle was picked up to be thrown, the reaching phase was significantly shorter than when it was picked up to pour into a container.

Social Intentionality

In the studies discussed above, different kinematic patterns were reported between several object-directed actions that varied in their end-goal intention. Importantly, these actions were all performed alone. In addition to acting on objects for personal purposes (nonsocial intentions), one may also hold intentions that incorporate a social component into an action sequence (social intentions). Actions with social intentions are directed at and intended to affect the behaviour of another person (Jacob & Jeannerod, 2005). Actions may be identical at the physical goal level, and thus serve the same function (e.g. to pick up the pitcher). However, the initial reach-to-grasp action kinematics will nevertheless differ depending on whether the intention is nonsocial (e.g. pour yourself a glass) or social (e.g. pass the pitcher to a co-worker; Ferri et al., 2010).

Using similar paradigms to those described above (i.e. reach-to-grasp for an object with different nonsocial intentions), recently studies have supported the proposal that kinematics differ between actions performed with social intent and nonsocial intent (Ansuini et al., 2010; Becchio, et al., 2008; Quesque et al., 2013; Quesque, et al., 2016; Sartori et al., 2009a; Sartori et al., 2009b; Straulino et al., 2016). For instance, Ferri and colleagues (2010) found that the act of picking up food to bring to one's own mouth (nonsocial intent) was executed with a faster reach-to-grasp movement time as compared to when the reach-to-grasp action was embedded within a sequence directed toward placing the food into another person's mouth (social intent). In line with this, Becchio and colleagues (2008) reported lower amplitude of peak velocity and higher wrist height when participants picked up an object to be placed in a partner's hands (social action), rather than a bowl (nonsocial action). The authors proposed that individuals take a careful approach when placing the object into the hand of another individual as compared to when acting alone. Obtaining the same result, Quesque and colleagues (2013) reasoned these movements were implicitly exaggerated (i.e. higher elevations and slower actions) to draw the attention of others. Sartori and colleagues (2009) suggested that social actions are characterized by motor patterns that reflect informative cues about the purpose of the action. These interpretations seem to be grounded on the assumption that the kinematic changes associated with social intentionality are related to communicative intent or ability.

There is ample support that nonsocial intentions and social intentions influence reach-to-grasp action kinematics (Sartori et al., 2011; Ambruster & Spikers, 2006; Ansuini et al., 2006; Marteniuk, et al., 1987; Ansuini et al., 2010; Ansuini et al.,2008; Becchio, et al., 2008; Ferri et al., 2010; Quesque et al., 2010; Quesque, et al., 2016; Sartori et al., 2009a; Sartori et al., 2009b). However, the fact that kinematic changes may be related to differences in after-grasp motor sequences, rather than social intention, gives rise to the debate of whether motor information at the kinematic level can be used to communicate and understand higher-order social intentions (Jacob, 2008; Jacob & Jeannerod, 2005; Kilner et al., 2007). Jeannerod and James (2005) argue that kinematic information may enable an observer to understand what the actor is doing (i.e. physical end-goal; e.g. picking up the pitcher) but not why (i.e. intention). They asserted that the same movements can serve different social and nonsocial intentions, and therefore, while we may be able to predict the end of the motor sequence, it is not sufficient to understand the end-goal intention (e.g. moving a pitcher to later drink vs. to be within reach of a co-worker). However, other researchers, including Becchio and colleagues (2008) claim to have provided evidence against this view by demonstrating that when the physical demands of the task do not change (i.e. pick up an object to be moved into a concave bowl, or a partner's hands in the same location), the kinematics vary depending on the intention (Becchio et al., 2008, Quesque et al., 2013). However, an astute proponent of Jeannerod's argument might still claim that the after-grasp motor action was not in fact identical, given that the end-goal intention of the action was either to place in the hands of a conspecific or a bowl.

Laidlaw, Culham & Goodale (2016) ruled out the possibility that kinematic differences were related differences in the after-grasp action sequence by equalizing the motor demands of actions with social and nonsocial intentions. Participants were instructed to reach toward and pick up a block, then move it to the center of the table. Critically, this action sequence was performed on every trial and did not differ based on what came next. The only thing that differed from the participants' perspective was the intention for the block to be collected by the participant across the table in the social condition, whereas it was not collected by the participant in the nonsocial condition. Different kinematics were reported for social and nonsocial actions during the reach-to-grasp phase, even when the subsequent motor actions and goals were exactly the same. Given that the only difference between the two actions was the expectation that the block would be picked up by another person, this evidence lends support to the idea that these kinematic changes are not simply due to subsequent differences in the action sequence. This leads to the possibility that these changes may be modulated by some communicative process, as suggested by Ciaramidaro, Becchio, Colle, Bara & Walker (2014), Bara et al. (2011), Ansuini et al. (2014), Sartori, Becchio, Bara & Castiellio, 2009 and Quesque et al., 2013).

Social Aptitude and Social Signaling

To further explore the notion that the intention mechanisms that modulate social action kinematics from nonsocial action kinematics are distinctly related to communicative processes, the present study examined individual differences in social aptitude. Social aptitude encompasses one's communicative abilities and social competence (e.g. ability to understand social cues, make inferences about people's intentions; Jones & Greenberg, 2015). If a communicative mechanism is modulating the kinematics for social actions, then it is reasonable to expect those with lower aptitude to exhibit smaller kinematic differences between actions with social and nonsocial intent (i.e. poor communication translates to kinematics), and similarly those with higher social aptitude to exhibit greater kinematic differences between actions with social and nonsocial intent (i.e. strong communication reflected by clear kinematic discrimination).

To test this hypothesis, the present study examined whether the magnitude of kinematic differences between social and nonsocial actions are correlated with self-reported social aptitude as measured by the Autism Quotient questionnaire (AQ; Baron-Cohen,Wheelwright, Skinner, Martin, Clubley, 2001). The AQ is a 50-item questionnaire that assesses the degree to which individuals in the non-clinical population possess traits associated with Autism-Spectrum Disorder (ASD). The AQ evaluates individuals based on five subcategories: social skills, communication, attention to detail, attention switching, and imagination, though the former two are of particular interest. Baron-Cohen (2001) and colleagues tested the AQ with undergraduate students and reported an average AQ score of 17.6 (*SD* = 6.40). The items on the AQ were selected from the triad of autistic symptoms (Rutter, 1978, Wing & Gould, 1979). The triad includes impairments in social communication (e.g. drawing inferences from cues, understanding and engaging in appropriate nonverbal behaviour), social relationships (e.g. initiating and maintaining relationships), and social imagination (e.g. flexible thinking, shifting perspectives; Wing & Gould, 1979). Therefore, the items evaluate the social abilities of interest.

Furthermore, there is evidence that individuals with ASD (as opposed to typically developing participants who are scored using the AQ) demonstrate both difficulties in social aptitude as well as intention-based action understanding and production. Nonverbal communication was investigated in ASD adults by Macdonald, Rutter, Howlin, Rios, Le contour, Evered and Folstein (1989). They showed that adults with ASD were less able than adults without ASD to produce both facial expressions and speech that express recognizable emotions. Similar results were found with respect to recognizing emotion in others: adults with ASD performed worse than adults without ASD on facial emotion recognition tasks and vocal emotion recognition tasks. Moreover, Cattaneo, Fabbri-Destro, Boria, Pieraccini, Monti, Cossu, and

Rizzolatti (2007) showed that children with ASD differ from typically developing (TD) children in the planning and organization of actions. Electromyographic activity (EMG) of the of mouth-opening muscle was recorded as TD and ASD children picked up food from a plate with the intention to either eat it or to place it in a container located near the mouth. For the reach-to-grasp-to-eat action, TD children exhibited increased EMG activity of the muscle during the initial motor act (reach-to-grasp). In ASD children, muscle activity only appeared to increase during the bring-to-mouth end phase of the action. Cattaneo et al. (2007) proposed that an organized motor chain (i.e. chain specifying the action sequence from start to finish based on end-goal intention) is selected prior to action execution in TD children, but is impaired in ASD children such that the intention is only incorporated into the action at the later phases. Therefore, in ASD children, intentions may not translate into kinematics at the outset of the action, unlike what is observed in TD children. Complementary results were found when TD and ASD children observed an actor perform the same two actions (i.e. pick up to eat and pick up food to it in a container near the mouth). This suggests that the ability to predict and understand intention from action observation may be impaired in ASD children.

While much research has looked at ASD deficits in the execution and understanding of actions with nonsocial intentions (Cattaneo et al., 2007; Centelles, Assaiante, Etchegoychen, 2013; Cook, Swapp, & Pan, 2014; Dowd, McGinley,Taffe, 2012; Fabbri-Destro, Cattaneo, Boria, 2009; Mari, Castiello, Marks, 2003), I am unaware of any study to investigate the execution and observation of actions with social versus nonsocial intent. Although ASD is associated with deficits in social communication, as well as intention production and understanding, it is unclear whether the two operate independently, if they are interrelated, or if one influences the other. For instance, individuals who experience difficulty in social situations may then fail to learn the skills necessary to pick up on intentions by observing others' actions. Alternatively, individuals who show diminished mirroring of others' actions, or lack robust intention-based action production, may be at disadvantage in social settings where understanding why other individuals are acting in particular ways is important for group cohesion and successful interaction. As such, the present study investigated whether AQ scores, particularly it's Social Skills and Communication subscales, were correlated with social intention-based kinematic changes.

The aims of the current study were two-fold. The first was to replicate the experiment and results of by Laidlaw and colleagues (2016). A participant seated opposite to a confederate was instructed to reposition a block on the table between them. In the social (Give) condition, the participant heard the word "give," where they then picked up an object (i.e. a small block) to place it in the center of the table. The object was subsequently collected by a confederate. The same task was performed in the nonsocial (Place) condition after hearing the word "place." However, the block was not collected by the confederate, who remained seated across the table from the participant. Infrared motion tracking markers were attached to the wrist, thumb and index finger of the right hand to record participants' reach-to-grasp movements using a motion tracking system (Optotrak Certus). Following the motion tracking portion of the study, participants completed the AQ. By correlating the AQ with the difference between the kinematic profiles of the social and nonsocial actions, the second aim of this study was to determine if the magnitude of the difference was related with social aptitude, as measured by overall AQ, or by its Social Skill or Communication subscales.

Since social aptitude and the AQ reflect social cognition (i.e. the way we process information about others in social situations), this investigation provides insight into whether we process information about people the same way we process information about other objects. It was expected that AQ scores would be negatively correlated the magnitude of the difference between the actions. That is, individuals with higher AQ's (i.e. poor social aptitude) should exhibit a smaller kinematic difference, given the assumption that the kinematic modulation of social actions is communicative-based. To strengthen the conclusions of the current results, this experiment will need to be repeated with actions that have different nonsocial intention (e.g. move plate away because you don't like food vs. move to eat after), to ensure that these differences are not correlated with AQ. This will confirm that the change is specific to social intention, not intentionality in general. However, if the results revealed that the group varies in AQ but does not exhibit differences in the degree to which the kinematics change, this would speak against the idea that social cognition is involved in modulating these actions. It is possible that ASD social deficits and autistic traits in the general population are a result of intention planning and understanding, rather that atypical social behaviour causing the lack of communicative cues.

Methods

Participants

Thirty-nine participants (15 males, 24 females; mean age = 18.83 years) completed this experiment. Participants self-reported normal or corrected-to-normal vision and were right handed, as assessed by the Edinburgh handedness inventory (Oldfield, 1970). All procedures were approved by Western University's Research Ethics Board for Non-Medical Research Involving Human Subjects (NMREB). Participants were Western University undergraduate students recruited from the psychology participation pool or through posters and were compensated with course credit or payment. Participants provided written informed consent and were aware that they could withdraw at any time (see Appendices A and B). Nine participants who completed the study were excluded due to significant data loss, likely due to equipment or user error, leaving a total sample of 30 participants (15 males, mean age = 18.85 years).

Procedure

An Optotrak Certus motion tracking system recorded the kinematics of participants' reach-to-grasp actions as they picked up an object to move it to a central (target) location, where it was either collected up by a confederate (social [Give] condition), or not (nonsocial [Place] condition). One block (36 trials) of both experimental conditions were administered to all participants in a counterbalanced order (total 72 trials). The first six trials in each block were considered practice trials and thus excluded from analyses.

One confederate participated in each testing session. There were two female confederates; one confederate (18 years of age) participated in 19 sessions and the other (19 years of age) participated in eleven. They were trained to respond consistently across sessions and similarly to each another. They were unaware of the specific hypotheses under investigation. The confederate posed as a participant for each testing session and arrived in the participant waiting room prior to testing. Upon entering the testing room, the participant and confederate were asked to choose a number between 1 and 10 to determine who would take on the more active role in the task (i.e. interact with the block in both conditions). The results were rigged so that the participant always chose the closer number, which meant they would be assigned to the more active role. The purpose of this was to make participants believe that their roles were not pre-determined.

The participant and confederate were seated across a table, facing each other at eye level. In both conditions, the participant and confederate began each trial in a predefined starting position in which their hand was placed on a mesh pad (see Figure 1) with the thumb and index finger lightly pinched together, pressing down on the mesh pad to make contact with the surface of the table. They were requested to remain in this position at all times that they were not performing an action. At the beginning of each trial, the object was placed in one of three initial positions (close, center, or far; see Figure 2). The object's initial position was equally likely to be any of the three positions, and the order of positions was random.

The participant was instructed to reach and grasp the object once they heard the auditory cue through their headphones: "place" (~ 350 ms) in the nonsocial (Place) condition; "give" (~ 350 ms) in the social (Give) condition (see Figure 1). At the same time, the confederate heard "ready" through their headphones to inform them of the start of the trial. After this cue, the participant was to use their right hand to reach out to pick up the object and move it to the target position at the center of the table (See Figure 3; reach-to-grasp action evaluation). It was requested that this action be performed naturally (e.g. speed, positioning) and the object be placed accurately (i.e. within the square target landmark location). The participant then returned their hand to the starting position. While the participant was performing the action sequence, the confederate's hand remained motionless at their starting position. Note that this exact action was performed in both conditions.

After placing the object down on the table, the participant heard the word "wait" (~ 400 ms) through their headphones, in which they were to wait in starting position for the next cue. An auditory cue was simultaneously delivered to the confederate: "wait" (~ 400 ms) in the Place condition; "go" (~ 400 ms) in the Give condition.

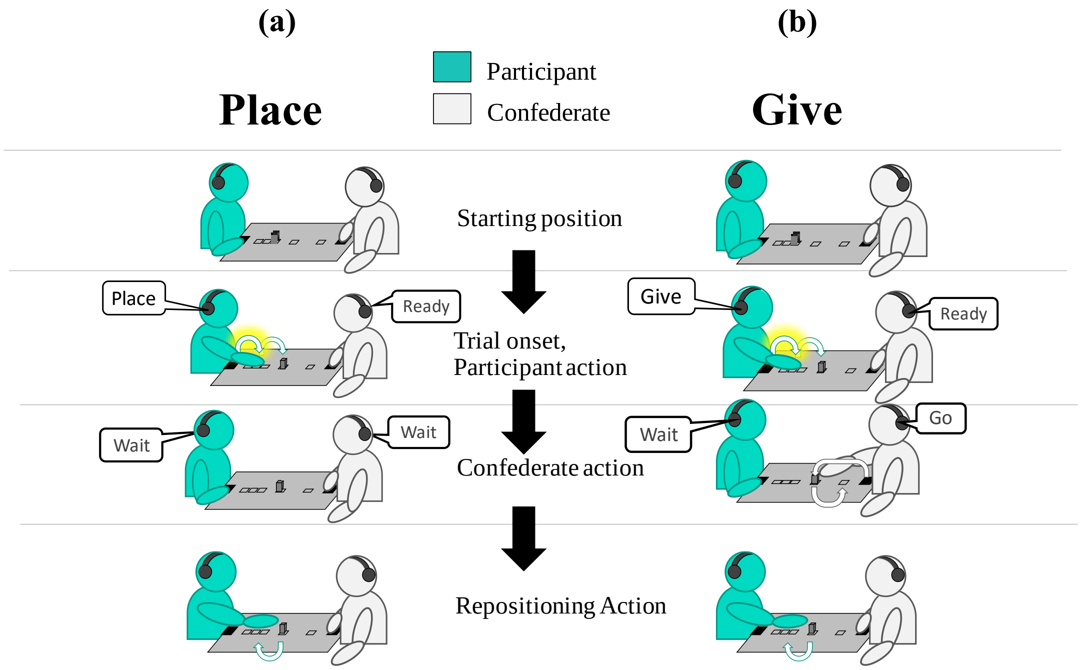


Figure 1a,b. 1a. Place (nonsocial) condition. The participant and confederate began in starting position with their hands on a mesh pad. The start of the trial was signaled by an auditory cue (“place” for the participant, “ready” for the confederate). The participant then used their right hand to the move object from one of the three initial positions (close, center, far) to the center of the table (target position; the reach-to-grasp evaluation is highlighted in yellow). The auditory cue “wait” then signaled the participant and confederate to remain in starting position. The end of the trial was signaled by an auditory beep (trial over). Next, the participant received an auditory repositioning instruction, “close,” “center,” or far, in which they then relocated the object to the designated starting position. 1b. Give (social) condition. The participants’ task was identical to the Place task, however the onset of the trial was signaled by “give.” After the object was placed in the center, the confederate was signaled to move the object by the cue “go.” The confederate then moved the object to the end position. After the beep (signifying the end of the trial), the confederate returned the object to the center, where it as then repositioned by the participant.

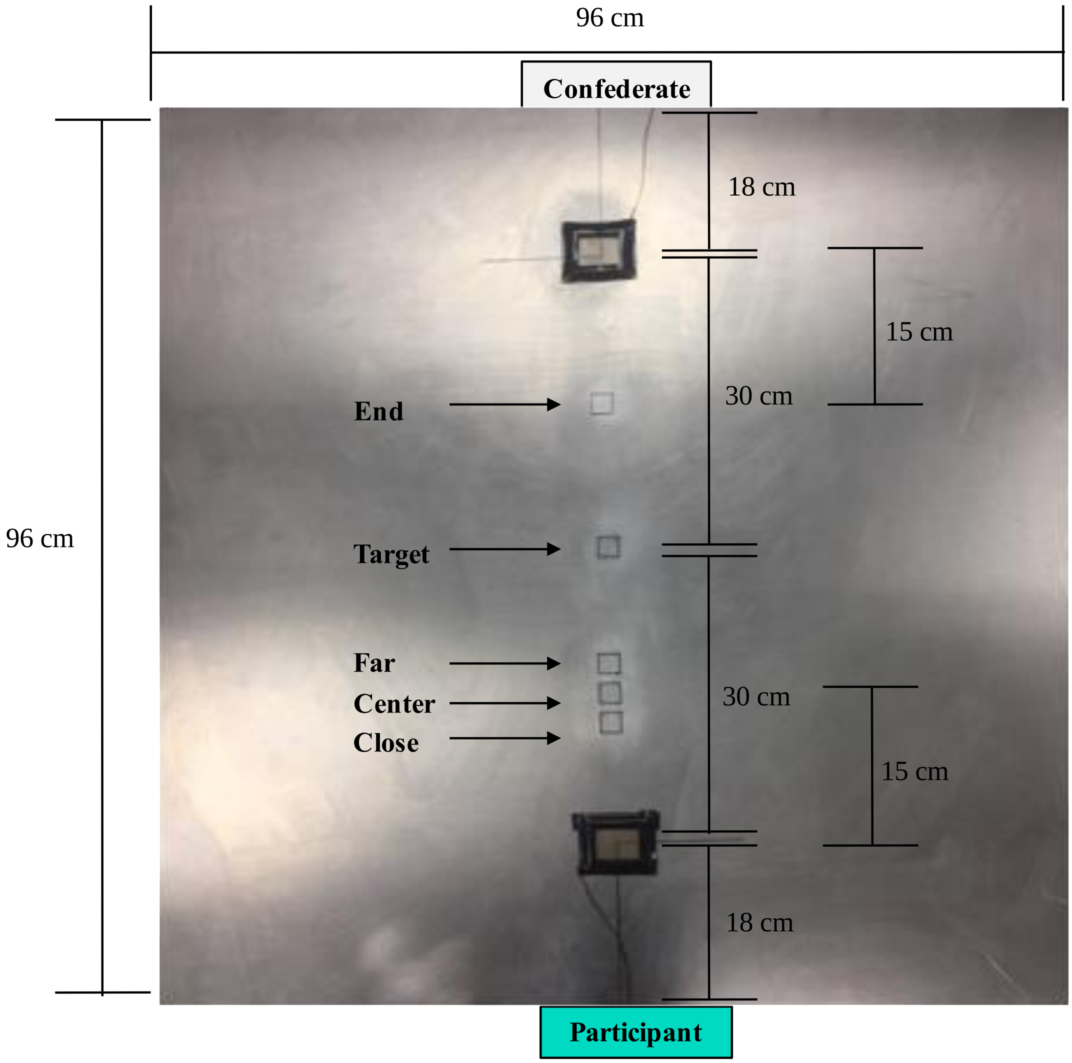


Figure 2. The working surface with the two starting pads (marked at 18 cm), three initial positions (close, center, far), target position and end position.

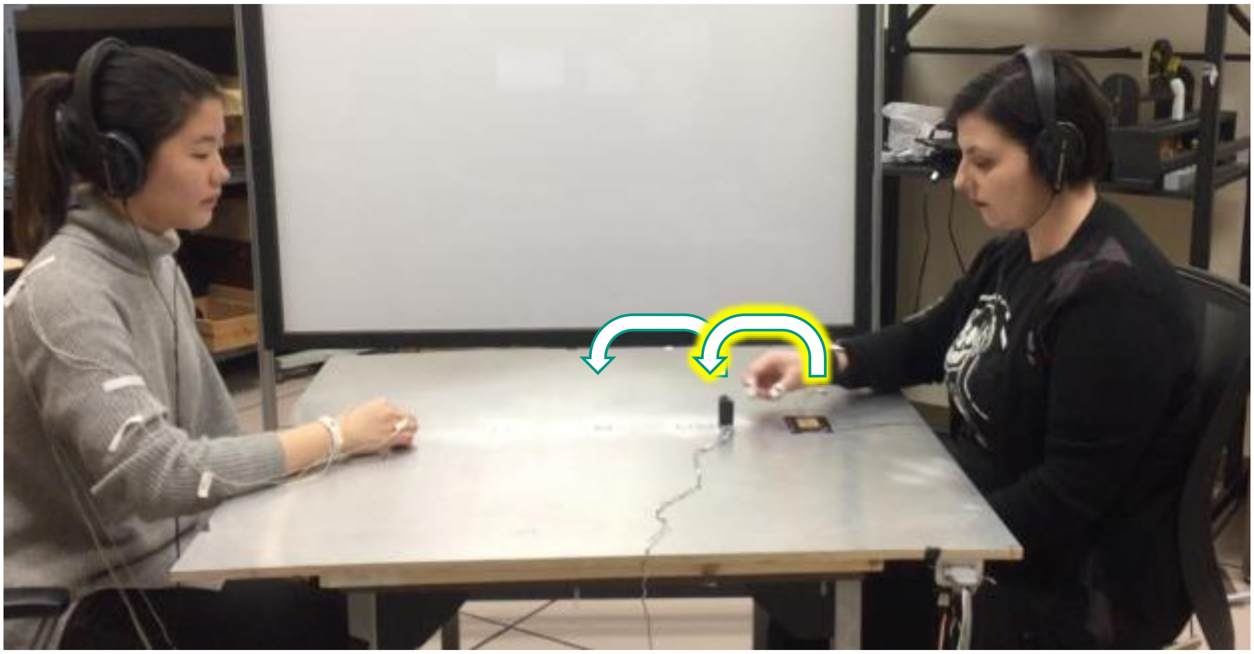


Figure 3. The participant (right) performing the initial reach-to-grasp action that was evaluated for analyses (highlighted in yellow).

In the Give condition, upon hearing “go”, the confederate was to reach out to pick up the object and place it on the end position, 15 cm away from the mid position, closer to the confederate (see Figure 1b). In the Place condition, the partner remained in starting position during this time without interacting with the object (see Figure 1a).

In both conditions, the confederate and the participant were then presented with an auditory tone (~ 300 ms) which signified the end of the trial. In the Give condition, the confederate then returned the object to the central target position so that it was within reach of the participant. A repositioning instruction (“close,” “center,” or “far”) was then delivered through the participant’s headphones. The participant was to then move it from the target position to the designated initial position (see Figure 1). Both the participant and confederate waited at the starting position until the next trial.

Note that the participant action sequence was identical in both conditions. The critical difference was the intentional component (i.e. passing it to the center to be picked up by the other person versus to not be picked up). A mean and standard deviation of the time it took for the confederate to complete the action (Give condition) was calculated during pilot testing. This was used to determine the length of “wait” period in the Place condition and thus equate the trial length in both conditions.

After the motion tracking portion of the study, participants completed the Autism Quotient questionnaire (AQ; Baron-Cohen et al., 2001). The 50 items on the questionnaire assess the degree to which individuals in the non-clinical population possess traits associated with Autism-Spectrum Disorder (ASD). Higher AQ scores (scored out of 50) are indicative of a greater number of traits associated with ASD. Autistic tendencies are organized into five AQ subscales (each scored out of 10), though only Social Skills, Communication and total AQ scores were of interest. Participants were fully debriefed following participation. After being informed that the confederate was not a participant, they read and signed a deception acknowledgement form (see Appendix C) to re-consent to the use of their data.

Apparatus

The working surface was a square aluminum table (96 x 96 cm; see figure 2). Two copper mesh pads (7 x 6 cm) were attached to the surface of the table such that they would make contact with the table when pushed on. Mesh pads were both 18 cm anterior to each persons' midline (i.e. served as starting positions). The object was a rectangular aluminum block (diameter 2cm, height 4cm). Five square landmark positions (2 x 2 cm; three initial positions, one target position and one end position), were spaced between the two starting positions and marked on the table using permanent marker. The center of each initial position from the participant's mesh pad was a distance of 12 cm (close), 15 cm (center), and 18 cm (far). The target landmark position was centrally located 30 cm from both mesh starting pads, and 15 cm from the end position landmark. The table had a very mild 5V electric charge sent to it. When the object was placed on the table or the mesh pad was pressed onto the table, it completed a circuit; when lifted off, the circuit was broken. In this way, the exact timing of lift off and "put down" could be recorded by the computer.

Participants' movements were recorded by two Optotrak motion tracking systems (Optotrak Certus; located above the table; and 254 cm left of the participant; sampling rate 200 Hz). These systems captured the three-dimensional positions of infrared light-emitting diodes (IREDs), which were taped to the participants' radial side of the wrist, ulnar side of the thumb nail, and radial side of the index fingernail on the right hand (see Figure 4). The IREDS were attached to the confederate at the same three points. This was to ensure that the participant believed that the confederate was being tested as well.

Data processing

Statistical analyses were limited to the wrist IRED due to errors in motion detection of the thumb and index finger for several participants. The kinematic parameters of interest (dependent variables) for the reach-to-grasp component of the action included the following: reaction time (RT; time duration between auditory cue and when the hand lifts off mesh sensor; reported in ms), movement time (MT; time duration between onset of action and offset of action, as defined by velocity threshold criteria, below; ms), amplitude of peak velocity (APV; maximum velocity reached within action; $mm \cdot s^{-1}$), time to peak velocity (TPV; time duration between onset of action and peak velocity; ms), amplitude of peak height (APH; maximum height reached by wrist IRED in the Z plane; mm), time to peak height (TPH; time duration between onset of action and peak wrist height**;** ms).

Data were converted to .txt files of XYZ and time values using an in-house program, OTDisplay. An in-house MATLAB script which incorporated components from the RTMocap toolbox (Lewkowicz and Delevoya-Turrell, 2015) was used for pre-processing and analysis. Briefly, this included data interpolation, smoothing, and kinematic determination. First, to compensate for brief disruptions of IRED detection, the data was first interpolated using inpaint nans (available: http://www.mathworks.com/matlabcentral/fileexchange/4551). A dual fourth-order low-pass Butterworth filter (fc = 15 Hz) was then used to smooth the data for noise. Kinematics as described above were calculated using RTMocap_kinematics function. A movement was defined if the following criteria were met based on data from the wrist IRED: if

Figure 4. Participant's hands with IRED sensors attached to the thumb, index finger and wrist.

velocity exceeded 20 mm · s^{-1}, reached a peak velocity of at least 120 mm · s^{-1}, and hit a local minima that was at least 100 mm · s^{-1} less than what was recorded at the peak. For each trial, profile plots of the movement and its velocity were generated and manually inspected to confirm appropriate movement segmentation and IRED recording.

Trials with excessive noise (i.e. no clear reach-to-grasp movement), mislabeled timestamps (i.e. due to erroneous parsing in RTMocap kinematics), or incomplete movements were excluded. Finally, trials were excluded if reaction time or movement time was less than 150 ms or greater than 1250 ms. For each participant, error trials were calculated as a percentage of total trials. To ensure sufficient trial numbers to calculate average kinematics, participants were excluded if they failed to have a minimum of 20 useable trials per condition, eliminating nine participants. For the trials to be used in analyses, error trials constituted 5.33% of non-practice trials and were thus excluded. For each of the 30 participants include in analyses, means were calculated for each kinematic variable across the usable trials for the Give and Place conditions. A kinematic difference score was then computed for each participant by subtracting the mean Give value from the mean Place value. One-sample t-tests were then used to compare the difference scores to zero to determine whether the differences between the give and place kinematic parameters were significant. Pearson correlations were run to evaluate the correlation between difference scores and AQ (total and relevant subscales).

Results

In brief, the results provide evidence of the effect of social intention on movement kinematics; key kinematic parameters differed for social (Place) actions and nonsocial (Give) actions. Further, the degree to which several kinematic parameters differed based on social intentionality was significantly correlated with participants self-reported communication skills. Below is the data in support of these results.

Kinematic Effects of Social Intention

Replicating previous research, different kinematics emerged for actions in the social (Give) and nonsocial (Place) conditions (see Figure 5). Social (Give) actions were initiated (RT) significantly faster than nonsocial (Place) actions, $t(29) = 2.74$, $p = .010$. The average duration (MT) of the reach-to-grasp action differed between conditions; participants performed the movement significantly faster in the social (Give) condition in comparison to the nonsocial (Place) condition, $t(29) = 5.09$, $p < .001$. APV during the reach was significantly higher, $t(29) = -5.25$, $p < .001$, in the social (Give) condition, and was reached at an earlier time in the movement (TPV; $t(29) = 4.44$, $p < .001$) than in the nonsocial (Place) condition. No effects of social intention were found for APH ($p = 0.372$) and TPH ($p = .091$). The mean values of the kinematic parameters are presented in Table 1.

Social Aptitude (AQ) Correlation with Kinematic Effects of Social Intention

Extending past research, the differences in reach-to-grasp duration (MT) and peak velocity (APV) between the conditions were significantly correlated with AQ communication subscores (see Figure 6). There was a negative correlation between MT difference scores and AQ communication, $r(28) = -.43$, $p = .017$, such that the duration of social (Give) actions decreased more for participants with lower AQ communication subscores (i.e. indicating they have higher communication skills) relative to participants with higher AQ communication (i.e. lower communication skills). AQ communication was positively correlated AVP, r $(28) = -.55$, $p = .002$, such that participants with lower AQ communication subscores (i.e. higher communication skills) exhibited a larger increase in peak velocity for social (Give) actions in

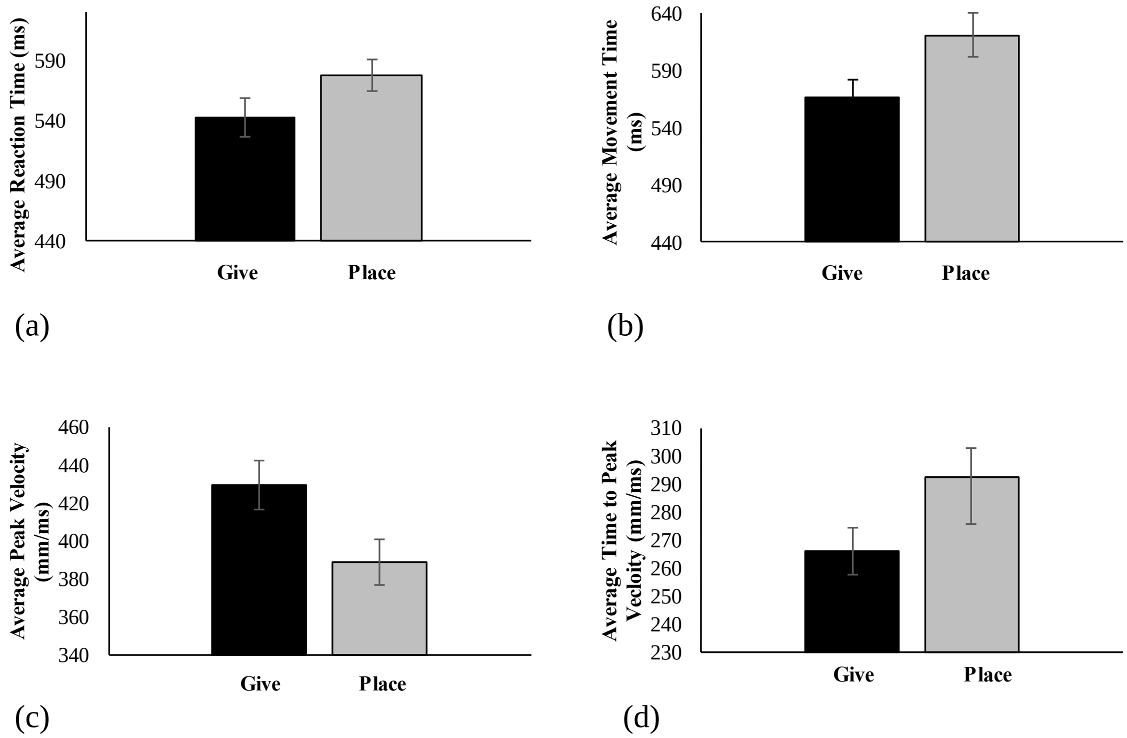


Figure 5. Mean values of kinematic measures for the Give and Place experimental conditions [reaction time in milliseconds (a), movement time in milliseconds (b), peak velocity in millimeters per milliseconds (c) and time to peak velocity in millimeters per milliseconds]. Bars represent standard error of the mean values.

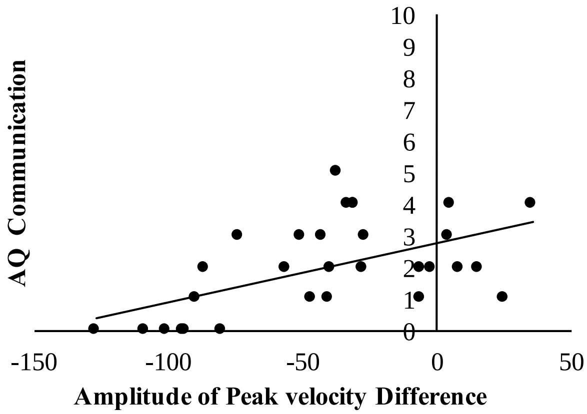
Table 1

Means of Kinematic Measures and Difference Scores

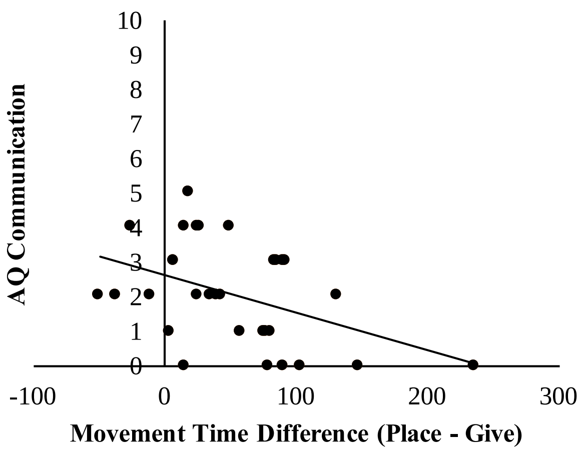
Kinematic Parameter	Condition: Give	Condition: Place	Difference (Place – Give)
Reaction Time (RT)	542.70 (15.61)	577.786 (12.91)	35.08 (12.82)*
Movement Time (MT)	566.03(16.63)	620.56 (19.41)	54.54 (10.72)**
Amplitude of Peak Velocity (APV)	429.53 (12.86)	388.56 (11.20)	-40.97 (7.81)**
Time to Peak Velocity (TPV)	265.92 (8.38)	292.16 (10.65)	26.25 (5.99)**
Amplitude of Peak height (APV)	60.40 (3.45)	58.40 (3.00)	-2.00 (2.20)
Time to Peak Height (TPH)	294.44 (23.49)	314.77 (26.56)	20.33 (11.64)

Note. Mean values for kinematic parameters (standard error in parentheses) of reach-to-grasp actions.

*p < .05, **p < .01. Indicates Difference score is significantly differently than zero.



(a)



(b)

Figure 6. Correlation between AQ communication scores and the difference between Give and Place kinematic measures [movement time in milliseconds (a), amplitude of peak velocity (b)].

comparison to those with higher AQ communication scores. Kinematic parameters did not significantly correlate with total AQ score or AQ social skills subscores (See Table 2). The AQ scores ranged from 9 to 23 (M = 17.60, SE = 0.33).

Discussion

The aim of the present study was to investigate the influence of social intention on movement kinematics, and whether it is related to social aptitude. Participants picked up and moved an object to the center of a table, where it was then within reach of a confederate seated at the opposite end of the table; it was then either collected by the confederate (social Give condition), or not (nonsocial Place condition). As hypothesized, reach-to-grasp kinematic parameters differed significantly for actions with social (Give) and nonsocial (Place) intentions, despite equivalence in motor goal. Furthermore, in line with predictions, participants with higher self-reported communication skills exhibited greater kinematic changes related to social intention than participants with low self-reported Communication skills. In contrast to hypotheses, self-reported Social Skills and total AQ scores did not significantly correlate with kinematic changes related to social intention. This section will review how the findings fit with existing literature, address the limitations and implications of the current findings, and outline directions for future research.

Kinematic Effects of Social Intention

While several studies have reported an effect of social intention on action kinematics, this effect has been investigated by comparing actions with different after-grasp movements (e.g. Ferri et al., 2010), end-goals (e.g. Becchio et al., 2008a), or subsequent actions (e.g. Quesque et al., 2013). Therefore, it is unclear whether these kinematic changes were driven by differences in the actions sequences, rather than social intentions. As such, there is still debate over whether the

Table 2

Reach-to-Grasp Kinematic Parameters and Correlation with Mean AQ and Subscale Scores

		AQ Subscale	
Kinematic Parameter	Total AQ	Communication	Social Skills
Reaction Time (RT)	0.024	-0.228	-0.284
Movement Time (MT)	-0.072	-.434*	0.006
Amplitude of Peak Velocity (APV)	0.029	.545**	0.278
Time to Peak Velocity (TPV)	0.276	-0.188	0.219
Amplitude of Peak height (APH)	0.208	0.182	0.344
Time to Peak Height (TPH)	0.077	-0.12	0.16

Note: *r* value with *p*-value in parentheses

*p < .05, **p < .01. Indicates correlation between kinematic difference score and self-reported measure is significant.

reported kinematic changes are unique in that they are related to social intention and whether they serve to enhance communication (Jacob & Jeannerod, 2005; Jacob, 2008; Kilner et al., 2007)**.** We provide evidence of kinematic effects of social intention by equalizing the task demands, making participants perform identical actions in the Give and Place condition, with no differences in after-grasp actions. In doing so, the kinematic differences reported above cannot be explained by different after-grasp intentions and action sequence goals. In the present study, social (Give) actions were initiated (RT) and executed (MT) faster, resulting in higher peak velocities (APV), earlier (TPV) in the action. It is worth nothing that these findings are not consistent with earlier studies reporting that relative to nonsocial actions, social actions were more exaggerated. That is, they reported longer reaction times, longer movement durations and higher wrist amplitudes (e.g. Quesque et al.,2013, Becchio et al., 2008b). However, the current results are consistent with Laidlaw et al. (2016; faster reaction time, lower wrist height for social actions). The findings are nevertheless consistent with fact that kinematic differences were observed between social and nonsocial actions.

Exaggerated movements have been interpreted as a means of attracting other peoples' attention to signal the intent to interact prepare them to respond appropriately (Quesque et al., 2013). Further, slower movements have been described as a more careful approach that would enhance accuracy during interaction (Becchio et al., 2008). Discrepancies between current and previous results may be attributable to the nature of the task under investigation. For example, Ferri et al., (2010) reported that when participants picked up food to put into their own mouths (nonsocial intention) versus an experimenter's mouth (social intention), self-feeding actions were characterized by higher APV and earlier TPV. The self-feeding action, however, is a highly automatic action and thus requires less effort and control to perform. Perhaps this explains why the conspecific-feeding action, which is highly demanding of accuracy and control, was performed slower. In another study, when participants moved an object into a concave base (nonsocial intention) versus experimenter's hands (social intention), the reach phase was characterized by longer movement duration (Becchio et al., et al., 2008b). The authors stated that the motor intention was identical, however evidence suggests that the size of the target location (concave base vs. hands) influences the reach-to-grasp kinematics (Rosenbaum & Jorgensen, 1992; Johnson-Frey, McCarthy & Keen, 2004. The studies above illustrate that previous reports of kinematic patterns related to social intention may reflect extraneous influences such as the ease with which the action was performed and the size of the target location. However, in the present study, the experimental design was modified to eliminate the influence of different after-grasp action sequences and end-goals. This led to a different pattern of results (i.e. social actions were initiated and performed faster than nonsocial actions), which were similar to those reported by Laidlaw et al. (2016), who employed an identical paradigm. Faster social actions reported in the current study may reflect the desire to be an efficient partner during social interaction.

Kinematic Effects of Social Intention and Correlation with AQ Communication

In addition to demonstrating the effect of social intention on kinematics, we attempted to gain insight into whether these changes serve a communicative function by examining whether they relate to communicative ability. Indeed, analyses confirmed that AQ communication scores were significantly correlated with the degree of kinematic differences between social (Give) and nonsocial (Place) actions. Participants with superior self-reported communication skills (i.e. lower AQ Communication scores) exhibited greater social kinematic changes than those with lower self-reported communication skills (i.e. higher AQ Communication scores). Successful communication requires that the recipient recognizes and correctly understands the signal

(Sartori, 2009). Accordingly, from the perspective of the actor, producing greater kinematic differences between social and nonsocial actions would be more likely to be distinguished and recognized by the recipient, thereby improving interpersonal communication. This finding thus implicates the role of a communicative mechanism in modulating these changes (i.e. better communication is reflected in kinematics).

It is important to note that these results do not constitute direct evidence of effect communicative intention causing social intention-based kinematic changes. Rather, the results are simply correlational, and further research is necessary to draw causal conclusions. Given the nature of correlational research, the reported findings may be influenced by extraneous factors. One possibility is that participants with higher self-reported communication skills interpreted the task differently than those with lower self-reported communication skills. Participants with higher communication skills may have interpreted the Give task as an interactive task, in which they would need to communicate (i.e. signal their intention to give the block to the other person) and act efficiently (i.e. quickly) for successful performance. On the other hand, participants with lower self-reported communication may have been less attuned to the other person's role. After acknowledging that their motor task was identical in both conditions, they may have simplified the task instructions to be identical in both conditions, thus dismissing the intention to give. If the intention to give is not incorporated into motor planning, social (give) actions of participants with lower communication scores may look one of at least two ways: they would resemble the nonsocial (place) actions of the high communicators, or they would look like something in between the social and nonsocial actions of the high communicators. Nonetheless, equalizing the task instructions would account for the resulting minimal kinematic changes displayed by participants with lower self-reported communication. Therefore, faster social (Give) actions may reflect the intention to be an efficient partner (rather than the intention to communicate), which was associated with understanding of the task and communication skills.

The correlation between Communication skills and the degree of kinematic changes is suggestive of the intention to communicate in the Give condition. While communicative intentions are a form of social intentions (i.e. intentions directed toward another person; Bara, 2010), what distinguishes the two is that communicative intentions are intended to be recognized by a recipient (Sartori, 2009). Modifying the experimental design to promote communication will likely yield stronger correlations, assuming it is true that the intention to communicate is reflected in action kinematics. For example, rather than administering the Give and Place trials in two separate blocks, the trials can be combined into one block in a randomized order. If the confederate is not aware of the trial type until the block is placed in the center by the participant, the participant will be more inclined to communicate their intention to the confederate to give them time to prepare the appropriate motor response (i.e. collect the object vs. wait). If all participants intend to communicate their intention to give the object to the confederate, perhaps a stronger correlation between communication skills and communicative-intention based kinematic changes will result. Further, the confederate’s reaction time would be indicative of whether they are able to read the cue and use it to act efficiently. This would also strengthen the evidence that kinematic changes facilitate communication.

Additional investigations will provide insight into the mechanisms underlying this relationship. First, it will be necessary rule out the possibility that the lesser kinematic discrimination among individuals with low communication scores was related to difficulties incorporating intentions into their actions, rather than difficulties with social intentions. This can be done by comparing the kinematics of two actions with different motor intentions (e.g. reach to throw vs. reach to move) in a population of low communication individuals. If the kinematics are not differentiated based on motor intention, this would suggest that an impairment lies within the motor planning system (i.e. incorporating intentions into motor kinematics), which in turn may affect communicative ability.

If individuals with low communication scores show different kinematics between actions with different motor intentions, examining reach-to-grasp kinematics of two nonsocial intentions with equivalent motor intention (e.g. reach to move cup to drink later vs. reach to move cup out of the way) in individuals that range in communication skills will provide further insight. If there are significant kinematic differences between these two actions, and the degree of change is not correlated with communicative ability, this would lend support to the hypothesis that the lack of kinematic discrimination (i.e. between actions with social and nonsocial intentions) among individuals with low communication scores in the present study is related to social poor communication skills. However, if communicative ability is correlated with nonsocial kinematic changes, this would suggest that kinematic changes, regardless of social or nonsocial intention, serve a communicative function. To draw further conclusions, it would be useful to examine whether the mere presence of another person effects kinematic changes (i.e. although the actions have nonsocial intention, they may serve to inform others of nonsocial intentions). If high communicators show kinematic differences in the absence of other people, this undermines the hypothesis that these changes serve a communicative function (given that there would be nobody to communicate to). Lastly, if the kinematics do not differ significantly, this would indicate that kinematics only differ between actions with different end goals or social intentions, and thus strengthen the hypothesis that changes related to social intention enhance communication. Further, this would indicate that we process information about people differently than objects.

Kinematic Effects of Social Intention and AQ, AQ Social Skills

Contrary to the hypotheses, total AQ and AQ social skills were not correlated with the magnitude of kinematic differences between social (Give) and nonsocial (Place) actions. The AQ assesses both social and nonsocial aspects of behaviour and cognition. Therefore, the lack of correlation may be attributable to the items that do not reflect social aptitude. A measure with a narrow focus on social communication skills is therefore likely more appropriate. Similarly, a closer inspection of the items that constitute the social skills subscale revealed that it may not have been a suitable measure of the construct of interest. The social skills domain is broadly concerned with the preference to be around others, as well as the ability to socialize and build relationships. The communication domain, however, captures the ability to express oneself and understand others in an appropriate, effective manner, as well as achieve a shared mental state during interaction (see Appendix D). While social skills, such as building relationships, may rely on communication skills, there are certainly other traits that are necessary to successfully build and maintain relationships. As such, the communication measure is more reflective of the social communication skills we aimed to measure. Accordingly, this finding fits reasonably with our hypotheses.

The current results revealed that social skills associated with autism were not related to social kinematic changes. It is possible that social skills are more relevant for understanding others' intentions, rather than expressing intentions. In light of this, Lewkowicz et al. (2015) reported that when participants observed an actor reach toward and grasp an object to either use it (nonsocial intention) or give it to a co-actor to use (social intention), those with superior social skills correctly identified the actor's intention more often. As such, it is important not to reject social skills as a factor related to the ability to understanding intentions through action. A direction for future research would be focusing on individual differences in social and communicative skills, and the ability to predict intention by observing an actors' movement. This will allow us to differentiate between communicative ability and social skills in the role of communicating vs. expressing intention, if the two play different roles.

Implications

Extensions of the current research will enhance our understanding of the mechanisms underlying ASD. ASD is assumed to lie on a continuum of social-communication impairment (Baron-Cohen et al, 2001). Further, ASD has also been found to be associated with difficulties in understanding and producing intention-based actions (Cattaneo et al., 2007). It is unclear whether there is a causal connection between the two deficits, if they are interrelated, or operate independently. To gain insight into how these deficits are related, we examined whether normal individuals (who discriminate between nonsocial intentions in reach-to-grasp actions; Ansuini, 2008) with high social and communication traits of autism express social intentions through kinematics. If the results did not reveal a correlation, this would suggest that social-communication impairments are not related to difficulties in understanding and producing intention-based actions. However, participants who rated themselves as having more communication difficulties did not discriminate their social and nonsocial action intentions (through kinematics) as clearly as those with fewer self-reported communication difficulties. To strengthen our understanding of whether the lack of social-intention-based kinematic changes are related to communication difficulties, future research will need to address whether communication skills correlate with the magnitude of kinematic differences between two nonsocial actions. If there is a correlation, this would indicate that deficits in social-communication deficits and discriminating intentions are interrelated. Conversely, no correlation would suggest that deficits in discriminating intentions are independent of social-communication impairments.

To further extend our knowledge of the underpinnings of ASD symptoms, future research can explore whether failure to differentiate intentions (in actions) leads to social-communication difficulties, or vice versa. In regard to the former, it is possible that difficulties communicating and interaction in a social setting may result from the inability to appropriately use nonverbal cues to communicate and understand intentions. For example, if normal individuals do use kinematic signals in a social setting to detect others' intention to interact, the failure to signal the intention to interact through kinematics may be perceived by others as unwillingness to interact. Therefore, failure to express social intention through kinematics may affect how people read and judge them socially, and in turn, perpetuate social-communication difficulties. As such, it would be useful to investigate how these actions are perceived by others. Alternatively, it may be that social-communication difficulties result in early withdrawal from social settings and thus failure to learn the skills necessary to express and pick up on others' intentions through actions. It will be beneficial for future investigations to directly examine intention discrimination (communicating through kinematics and understanding through observation of kinematics) and individual differences in social-communication skills within the ASD population, of a wide age range. Comparing the measures of the ASD population to a non-clinical population will provide insight into when ASD self-reported social communication skills fall below those of the non-clinical population and whether this precedes group differences in communicating and understanding intention through kinematics.

Finally, it is worth noting the potential effect that a lower sample size may have had on the results and the conclusion drawn from them. The analyses in the present study were limited to 30 undergraduate students (ages 17- 25). There was a participant with an extremely large MT difference score (MT difference score = 235.86, *M* = 54,54). Given that only 30 participants were included in analyses, this potential outlier may have influenced the significance of the correlation between communication scores and MT. It is recommended that future studies examine a substantially larger sample size to avoid the influence of single outliers, and to increase diversity in the population to achieve a wider distribution of AQ scores. In addition, it is recommended that this is investigated within a larger age range. This will provide insight into the age at which social kinematic changes develop and whether they become more pronounced with age. Lastly, future investigations can benefit from employing more than one measure of social and communication. This will increase reliability of the results.

Conclusions. The results of the present study are supportive of the hypothesis that social intention-based kinematic changes are related to communication. In addition to demonstrating the effect of social intention, the current results demonstrate that the magnitude of this effect is related to communicative ability. The results thus extend our knowledge of the function of kinematic changes related to social intention. Further, the findings have implications for individuals who lack strong intention-based action production in social settings.

References

Adolphs, R. (2009). The Social Brain: Neural Basis of Social Knowledge. *Annual Review of Psychology*, *60*, 693–716

Ansuini, C., Begliomini, C., Ferrari, T., & Castiello, U. (2010). Testing the effects of end-goal during reach-to-grasp movements in Parkinson's disease. *Brain and Cognition*, *74*(2), 169-177.

Ansuini, C., Giosa, L., Turella, L., Altoè, G., & Castiello, U. (2008). An object for an action, the same object for other actions: Effects on hand shaping. *Experimental Brain Research*, *185*(1), 111-119. doi.org/10.1007/s00221-007-1136-4

Ansuini, C., Santello, M., Massaccesi, S., & Castiello, U. (2006). Effects of end-goal on hand shaping. *Journal of neurophysiology*, *95*(4), 2456-65.

Armbrüster, C., & Spijkers, W. (2006). Movement planning in prehension: do intended actions influence the initial reach and grasp movement? *Motor Control*, *10*(4), 311–329.

Bara, B. G. (2010). *Cognitive Pragmatics: The Mental Processes of Communication.*Cambridge, MA: MIT Press.

Bara, B. G., Ciaramidaro, A., Walter, H., & Adenzato, M. (2011). Intentional Minds: A Philosophical Analysis of Intention Tested through fMRI Experiments Involving People with Schizophrenia, People with Autism, and Healthy Individuals. *Frontiers in Human Neuroscience*,*5*, 7.

Baron-Cohen, S., Wheelwright, S., Skinner, R., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient : Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, *31*(1), 5-17.

Becchio, C., Pierno, A., Mari, M., Lusher, D., & Castiello, U. (2007). Motor contagion from gaze: The case of autism. *Brain*, *130*(9), 2401-2411

Becchio, C., Sartori, L., Bulgheroni, M., & Castiello, U. (2008**a**). The case of Dr. Jekyll and Mr. Hyde: A kinematic study on social intention. *Consciousness and Cognition*, *17*(3), 557-564.

Becchio, C., Sartori, L., Bulgheroni, M., & Castiello, U. (2008**b**). Both your intention and mine are reflected in the kinematics of my reach-to-grasp movement. *Cognition*, *106*(2), 894-912.

Becchio, C., Manera, V., Sartori, L., Cavallo, A., & Castiello, U. (2012). Grasping intentions: from thought experiments to empirical evidence. *Frontiers in Human Neuroscience*, *6*(May), 1-6.

Cattaneo, L., Fabbri-Destro, M., Boria, S., Pieraccini, C., Monti, A., Cossu, G., & Rizzolatti, G. (2007). Impairment of actions chains in autism and its possible role in intention understanding. *Proceedings of the National Academy of Sciences of the United States of America*, *104*, 17825-17830.

Centelles, L., Assaiante, C., Etchegoyhen, K., Bouvard, M., & Schmitz, C. (2013). From action to interaction: Exploring the contribution of body motion cues to social understanding in typical development and in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *43*(5), 1140-1150.

Ciaramidaro, A., Becchio, C., Colle L., Bara, B.G., Walter, H. (2014). Do you mean me? Communicative intentions recruit the mirror and the mentalizing system. *Social Cognitive and Affective Neuroscince;9*(7), 9–16.

Cook, J., Swapp, D., Pan, X., Bianchi-Berthouze, N., & Blakemore, S.-J. (2014). Atypical interference effect of action observation in autism spectrum conditions. *Psychological medicine*, *44*(4), 731-40.

Dowd, A. M., McGinley, J. L., Taffe, J. R., & Rinehart, N. J. (2012). Do planning and visual integration difficulties underpin motor dysfunction in autism? A kinematic study of young children with autism. *Journal of Autism and Developmental Disorders*, *42*(8), 1539-1548..

Fabbri-Destro, M., Cattaneo, L., Boria, S., & Rizzolatti, G. (2009). Planning actions in autism. *Experimental Brain Research* (Vol. 192, pp. 521-525).

Ferri, F., Campione, G. C., Volta, R. D., Gianelli, C., & Gentilucci, M. (2010). To me or to you? When the self is advantaged. *Experimental Brain Research*, *203*(4), 637-646.

Ferri, F., Campione, G. C., Volta, R. D., Gianelli, C., & Gentilucci, M. (2011). Social requests and social affordances: How they affect the kinematics of motor sequences during interactions between conspecifics. *PLoS ONE*, *6*(1).

Gangopadhyay, N., Madary, M., & Spicer, F. (Eds.).*Perception, Action and Conciousness: Sensorimotor Dynamics and Two Visual Systems*. Oxford University Press, USA.

Hamilton, A. F. de C., & Grafton, S. T. (2007). The motor hierarchy: from kinematics to goals and intentions. *Sensorimotor foundations of higher cognition*, pp. 381

Jacob, P., & Jeannerod, M. (2005). The motor theory of social cognition: A critique. *Trends in Cognitive Sciences*, *9*(1).

Jacob, P. (2008). What do mirror neurons contribute to human social cognition? *Mind and Language*, *23*(2), 190-223.

Johnson-Frey SH, McCarty ME, Keen R (2004) Reaching beyond spatial perception: effects of intended future actions on visually guided prehension. *Visual Cognition,11*, 371–399.

Jones, D. E., Greenberg, M., & Crowley, M. (2015). Early social-emotional functioning and public health: The relationship between kindergarten social competence and future wellness. *American Journal of Public Health*, *105*(11), 2283-2290.

Krach, S., Paulus, F. M., Bodden, M., & Kircher, T. (2010). The Rewarding Nature of Social Interactions. *Frontiers in Behavioral Neuroscience*, *4* (22).

Kilner, J. M., Friston, K. J., & Frith, C. D. (2007). Predictive coding: An account of the mirror neuron system. *Cognitive Processing, 8*(3), 159-166. doi.org/10.1007/s10339-007-0170-2.

Laidlaw, K.E.W., Culham, J.C., & Goodale, M.A. (2016). This is for you: Influences of social intentionality on reach-to-grasp actions. Poster presented at the annual meeting of The Psychonomic Society, Boston, MA, USA.

Lewkowicz, D., Quesque, F., Coello, Y., & Delevoye-Turrell, Y. N. (2015). Individual differences in reading social intentions from motor deviants. *Frontiers in Psychology*, *6*(August), 1-12. doi.org/10.3389/fpsyg.2015.01175

Macdonald, H., Rutter, M., Howlin, P., Rios, P., Le Conteur, A., Evered, C., & Folstein, S. (1989). Recognition and expression of emotional cues by autistic and normal adults. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *30*(6), 865-877.

Manera, V., Becchio, C., Cavallo, A., Sartori, L., & Castiello, U. (2011). Cooperation or competition? Discriminating between social intentions by observing prehensile movements. *Experimental Brain Research*, *211*(3-4), 547-556.

Mari, M., Castiello, U., Marks, D., Marraffa, C., & Prior, M. (2003). The reach-to-grasp movement in children with autism spectrum disorder. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1430), 393-403.

Mateas, M. and Sengers, P (1999*). Narrative Intelligence.* Amsterdam: John Benjamins Publishing Company.

Marteniuk, R. G., MacKenzie, C. L., Jeannerod, M., Athenes, S., & Dugas, C. (1987). Constraints on human arm movement trajectories. *Canadian journal of psychology*, *41*(3), 365-378.

Quesque, F., & Coello, Y. (2015). Perceiving what you intend to do from what you do: evidence for embodiment in social interactions. *Socioaffective neuroscience & psychology*, *5*, 28602.

Quesque, F., Lewkowicz, D., Delevoye-Turrell, Y. N., & Coello, Y. (2013). Effects of social intention on movement kinematics in cooperative actions. *Frontiers in Neurorobotics*, *7*(14). doi: 10.3389/fnbot.2013.00014.

Quesque, F., Delevoye-Turrell, Y., & Coello, Y. (2015). Facilitation effect of observed motor deviants in a cooperative motor task: Evidence for direct perception of social intention in action. *The Quarterly Journal of Experimental Psychology*, *69*(8), 1451-1463.

Rosenbaum DA, Jorgensen MJ (1992) Planning macroscopic aspects of manual control. *Human Movement Science, 11, 61*–69.

Sartori, L., Becchio, C., Bulgheroni, M., & Castiello, U. (2009a). Modulation of the action control system by social intention: unexpected social requests override preplanned action. *Journal of experimental psychology. Human perception and performance*, *35*(5), 1490-1500.

Sartori, L., Becchio, C., Bara, B. G., & Castiello, U. (2009b). Does the intention to communicate affect action kinematics? *Consciousness and Cognition*, *18*(3), 766-772.

Sartori, L., Becchio, C., & Castiello, U. (2011a). Cues to intention: The role of movement information. *Cognition*, *119*(2), 242-252. doi.org/10.1016/j.cognition.2011.01.014

Sartori, L., Straulino, E., & Castiello, U. (2011b). How objects are grasped: The interplay between affordances and end-goals. *PLoS ONE*, *6*(9).

Straulino, E., Scaravilli, T., & Castiello, U. (2016). Dopamine depletion affects communicative intentionality in Parkinson's disease patients: Evidence from action kinematics. *Cortex*, *77*, 84-94. doi.org/10.1016/j.cortex.2016.01.016

Wing, L., & Gould, J. (1979). Severe impairments of social interaction and associated abnormalities in children: Epidemiology and classification. *Journal of Autism and Developmental Disorders*, *9*(1), 11-29. Kluwer Academic Publishers-Plenum Publishers.

Appendix A

Letter of Information

Project Title: Behavioral studies of human perception and hand actions

Principal Investigator: Professor Jody Culham, PhD, Department of Psychology, Western University

Letter of Information

1. Invitation to Participate

You have been invited to participate in this research study of perception and hand actions because you fit the demographic visually and physically unimpaired adults age 18-55.

2. Purpose of the Letter

The purpose of this letter is to provide you with information required for you to make an informed decision regarding participation in this research.

3. Purpose of this Study

The purpose of this study is to investigate how humans use visual information to perceive the world and perform hand and/or eye movements.

4. Inclusion Criteria

Individuals who are between the ages of 18 and 55, with vision that is normal or corrected-to-normal (with glasses or contact lenses) are eligible to participate in this study.

5. Exclusion Criteria

The following individuals will be excluded from participating in the study:

1) individuals who are left-handed or ambidextrous
2) individuals with a history of strabismus (“lazy eye”) or amblyopia or who have poor depth perception
3) individuals with visual or neurological disorders or who have any condition that limits the dexterity of the arms hands or eyes.
4) individuals that are allergic to any of the food objects that might be used in the study (for example, blueberries or donuts).

If it is the case that any of these exclusionary criteria are met, you will still be compensated as outlined in section 9 of this form.

6. Study Procedures

If you agree to participate, you will be asked to view, judge or act upon objects or tools. In viewing tasks, you will simply be asked to look at stimuli. In judgment tasks, you will be asked to judge the size or orientation of an object, or discriminate between two or more actions. In action tasks, you will be asked to grasp and move an object, to eat a small food item, or to use a tool.

At the start of the session, we will have you fill out a questionnaire indicating how often you use your right and left hands. We will also briefly test your depth perception by asking you to tell us which of several visual stimuli appears closest to you. You may be asked to complete one or more additional personality-based questionnaires.

During the study you may have infrared light emitting diodes attached to your hands or arms to track motion. You may be asked to sit with your chin resting on a cushioned surface that is part of a table mounted eye-tracking device, or to wear a head mounted eye tracking system that attaches to your head like a helmet. This device will feel much like having a hockey or football helmet on your head. Your session may be recorded with video and audio equipment. You may still participate if you do not want to be video or audio recorded. You may complete the study with or at the same time as other participants.

The entire task will take one session lasting 1 hour. The task(s) will be conducted in the Brain and Mind Institute located in the Natural Sciences Building of the Western University campus. There will be a total of 500 participants taking part in this study.

7. Possible Risks and Harms

There are no known or anticipated risks or discomforts associated with participating in this study.

8. Possible Benefits

You may not directly benefit from participating in this study but information gathered may provide benefits to society as a whole which include contributing to the knowledge base about how vision is used for perception and action.

9. Compensation

If you are participating through the Psychology Research Participation Pool as a psych1000 student, you will receive one credit for research participation. If you do not complete the entire study or if you meet any of the exclusionary criteria you will still receive one credit. Students participating via the SONA system for a course other than psych1000 will receive participation credits equivalent to what is outlined in their course syllabus.

If you responded to a recruitment poster, you will receive $10 for research participation. If you do not complete the entire study or if you are found to meet the exclusionary criteria you will still be compensated $10.

10. Voluntary Participation

Participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no penalty. If you withdraw your consent at any point after agreeing to participate, your data will be discarded and your confidentiality will remain protected.

11. Confidentiality

All data collected will remain confidential and accessible only to the investigators of this study. If you agree to any additional uses listed on the separate Participant Photographic and Video Release Form, your likeness (e.g. video or photographs taken during the study) will be used only for the purposes that you consented to. If the results are published, your name will not be used. Any information pertinent to your identity will be kept in a locked cabinet in a secured room requiring key access for 5 years. After 5 years the information will be shredded and discarded.

12. Contacts for Further Information

If you require any further information regarding this research project or your participation in the study you may contact Professor Jody Culham, 519-661-3979, jculham@uwo.ca .
If you have any questions about your rights as a research participant or the conduct of this study, you may contact The Office of Research Ethics (519) 661-3036, email: ethics@uwo.ca.

Representatives of The University of Western Ontario Non-Medical Research Ethics Board may contact you or require access to your study-related records to monitor the conduct of the research.

13. Publication

If the results of the study are published, your name will not be used. If you would like to receive a copy of any potential study results, please contact Professor Culham, 519-661-3979, jculham@uwo.ca. Completion of the consent form attached with today’s date and your signature will be used as an indication of your consent to participate.

This letter is yours to keep for future reference.

Appendix B

Consent Form

Project Title: Behavioral studies of human perception and hand actions

Principal Investigator: Professor Jody Culham, PhD, Department of Psychology, Western University

I have read the Letter of Information, have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant's Name (please print): ______________________________

Participant's Signature: ______________________________

Date: ______________________________

Person Obtaining Informed Consent (please print): ____________________

Signature: ____________________

Date: ____________________

Appendix C

Deception Acknowledgement Form

Deception Acknowledgement Form

Behavioral studies of human perception and hand actions

By signing below, I am acknowledging and consenting to the use of mild deception in the study that I just completed. The researcher has explained to me the true purpose and methods used in the study that I participated in. They have fully debriefed me, and have explained to me the rationale behind using mild deception. Any questions I had were answered to my satisfaction. I understand that I can contact the researchers at any time in the future should I have further questions or comments.

Name of Participant: ________________________ (please print)

Signature of Participant: ________________________

Date: ________________________

Person Obtaining Consent: _______________________________ (please print)

Signature of Person Obtaining Consent: _____________________

Date: ________________________

Appendix D

Examples of AQ Subscale Items

Social Skills	I prefer to do things with others rather than on my own. I find social situations easy. I find it hard to make new friends. I would rather go to a library than to a party.
Communication	I find it easy to “read between the lines” when someone is talking to me. Other people frequently tell me that what I’ve said is impolite, even though I think it is polite. I know how to tell if someone listening to me is getting bored. When I talk on the phone, I’m not sure when it’s my turn to speak.