INDIVIDUALS WITH ASD: DIRECT ACTION POSSIBILITES

THE INFLUENCE OF DIRECT ACTION POSSIBILITIES ON MOVEMENT IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER

By

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ABSTRACT

The method by which individuals plan and execute movements is highly dependent on the environmental and task constraints. However, the way in which individuals view the world and objects differ amongst the population. This has profound implications for individuals who may have difficulties planning movement. There is growing evidence that individuals with Autism Spectrum Disorder have not only deficits in communication, but also in motor control (Glazebrook et al., 2009; Rinehart et al., 2006). Therefore, it is imperative to understand how and why these motor control differences arise in individuals with ASD and if there are ways in which these impairments could be alleviated. There is evidence demonstrating that brain connectivity in individuals with ASD may differ compared to controls (Frith, 1989). This may contribute difficulty when integrating highly cognitive information. Therefore, objects and scenarios that afford a high degree of action-perception coupling were explored to determine if (and how) individuals with ASD can use this more direct coupling to aid in the planning and execution of movement. Furthermore, we explored if these processes could be applied to interactions with other individuals. The findings of the study demonstrated that individuals with ASD did not appear to use the orientation of a handle (study one) to pre-plan responses to graspable objects (c.f. Tucker & Ellis, 1998). However, when the action component was further emphasized in the second study, the accuracy scores obtained were comparable to those of chronologically age and sex matched controls. This supports the notion that objects with high action-perception coupling can be used successfully by individuals with ASD to interact with other

individuals. The findings of study three demonstrated that individuals with ASD used the intended actions of a confederate to solve a Theory of Mind task, and thereby anticipate the motor intentions of the confederate. Overall, the findings of the dissertation suggest that the use of objects and scenarios that afford a high degree of action-perception coupling seems beneficial for individuals with ASD as they are able to use these objects to anticipate the possible actions that another individual may perform.

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GENERAL INTRODUCTION

It is possible that two individuals can look at the same object and experience different percepts. These percepts are necessary to plan and execute movements by sourcing individuals with the external information needed to successfully interact with the environment (e.g., where the objects are, what they are). However, this sometimes simple action of interacting with objects can be far more complex for some individuals. This is why it is important to understand the varying task-relevant information that different populations of people attend to when interacting with objects. This dissertation seeks to explore and understand some fundamental concepts in motor control as they may be applied to individuals with Autism Spectrum Disorder (ASD). To understand why such population specific differences in movement behaviours arise (Mari, Castiello, Marks, Marraffa, & Prior, 2003), an explanation of some of the modern concepts of human movement is warranted.

Different theoretical frameworks exist to explain human movement as it relates to interactions with specific environments. Two of the more prevalent theoretical frameworks are traditional information processing (e.g., Schmit, 1975) and direct perception (e.g., Gibson, 1977). A common theme to these frameworks is that the perceiver plays an active role in interpreting the environment by processing the available sensory information and/or by being aware of the consequences of interacting with the environment. Both have advanced our understanding of motor control for goal-directed actions however each school of thought interprets how movements occur differently.

In general terms, proponents of information processing argue that complex human movement is both computational and resource dependent. This means that humans incorporate or integrate different sensory information which the brain then uses to calculate the best available action using higher order cognitive resources. One such example of information processing is the Motor Schema Theory (Schmidt, 1975), whereby movement is thought to be controlled by accessing the stored information of previous situations similar to the current one by using "generalized motor programs" (e.g., Dubrowski, Proteau, & Carnahan, 2004). Generalized motor programs are believed to represent a schema that specifies how one performs a movement while execution parameters are adapted to perform a given movement within a specific context. The movement is then carried out by adjusting or correcting these parameters by using on-line or sensory feedback, which is used to re-evaluate the ongoing movement and make adjustments as necessary (e.g., Elliott, Helsen, & Chua, 2001; Fitts, 1962).

Meanwhile, direct perception theorists argue that perception of itself is the detection of information. Gibson (1977) proposed that there are specific "affordances" latent in the environment that are directly attainable by the observer. Thus, it is argued that there are certain perceivable actions that are permitted by the environment which influence the behaviour and movement of the individuals (Gibson, 1977).

Information Processing

One of the leading frameworks for motor control is the theory of information processing. This is an elegant, but computationally demanding model for interpreting how the brain views the external environment. An analogue to this model is the use of a "black box" wherein individual system inputs (e.g., afferent information) are processed and integrated within the black box (the brain) and in order to compute and execute an observable output (movement). Examples of this idea are described in the size-weight illusion and bone drilling experiments: the perceiver integrates the visual and haptic inputs to produce the size-weight illusion (Gordon, Forssberg, Johansson, & Westling, 1991 a-c) or the use of auditory cues when drilling through bi-cortical bones (Praamsma, Carnahan, Backstein, Veillette, Gonzalez, & Dubrowski, 2008). The information processing model suggests that individuals integrate sensory information to form a more complete percept than is represented with individual input systems. That is, the performance on the task was affected directly by the other modality (whether present or not present), and the individuals used the integrated information to plan their movements. This multi-sensory representation is then used to guide movements, as the perception of the weight of the objects is affected by the information of the visual modality (Gordon et al., 1991 a-c) and their force generation modulated by the auditory cues (Praamsma et al., 2008). Therefore an active processing of the information was suggested as a possible explanation for the force modulation.

One theory related to information processing is schema theory (Schmidt, 1975), which was directly influenced by Adams' (1971) Closed-Loop Theory of Motor Control. Adams (1971) proposed that slow, corrective aiming movements are composed of the memory trace (motor program responsible for initiating movement) and perceptual trace (guiding the limb to the correct location, formed from previous experience). The schema theory used some of the concepts from Adams (1971) and modified some of the perceived flaws. One such amendment was the notion of a schema, which suggests that individuals store a representation of similar skills as a unit (e.g., can throw baseball in many different ways) rather than storing all the different movements individually. That is, the different movements that can be employed to throw an object were believed to be categorically placed into a broader category of a skill (i.e., general throwing) that is parameterized for the different situations. This was proposed to alleviate the storage problem of having a motor program for all possible movement variations. The schema also contains past information and combines initial conditions with desired outcomes and uses feedback to regulate the movement (Schmidt, 1975). This model has been widely used and adapted to different research paradigms (Gordon et al. 1991 a-c; Praamsma et al., 2008) in motor control. This idea of a "top-down", computationally driven approach to human movement has remained a widely used method of describing movements.

Direct Perception of Affordances

To explain one of the differences between information processing and direct perception, a real life example will be discussed. If a person is catching a ball, both theoretical approaches agree that the act of catching the ball is a complex movement and that it can be performed with relatively ease, with practice. What differs between the two approaches is the explanation of how this skill is performed. Information processing theory would suggest that the catcher derives velocity and acceleration information from the ball and then uses this information to calculate both the time of the balls arrival and the spatial coordinates needed to successfully place the hand in the correct location to catch the ball. Direct perception theory instead suggests that the visual information provided by the approaching ball is rich enough to provide the information necessary to catch it. Instead of calculating the different variables from the array of sensory information provided, and from this creating a specific motor program, the action is simplified by directly perceiving what action can be performed by using only the available visual information. One such method is by exploiting the use of optic flow of the image on the retina to directly perceive the time-to-contact, termed "tau" (Lee & Reddish, 1981). The optic flow produces some direct information (e.g., rate of expansion of the image on the retina which gives information about the flight path, time-to-contact, etc.) of what action can be performed or afforded from the immediate situation (e.g., is it catch able or not).

To further illustrate direct perception theory, a closer inspection of affordances will be discussed. Gibson (1977) defined affordances as all "action possibilities" latent in the environment that are dependent on the perceiver's capabilities regardless of their ability to recognize them. An example of this concept would be human interaction with a horizontal surface. Since a horizontal surface allows for both sitting and standing, latent possibilities exist because the object affords multiple responses. Other researchers have also followed this line of reasoning as well. Warren (1984) demonstrated that individuals denote stairs as climbable that is proportional to their leg length. That is, the judgement made by tall and short individuals was dependent upon if the critical riser height (R_c) of the stairs was proportional to the length of the leg (L), with a critical ratio proposed to be

0.88. However, the idea of affordances has changed since being originally popularized by Gibson in 1977.

Indirect Perception of Affordances

There exists another manner in which researchers believe individuals perceive affordances. This other approach differs from the traditional direct perception view on affordances as it implies slightly more cognitive input into the perception of affordance. That is, the affordance created is not necessarily directly observable, but instead a result of an action or experience. For example, Norman (1988), who later admitted to incorrectly using this phrase, modified the term to a "perceived affordance" (Norman, 1999). That is, action possibilities are dependent not only upon the physical nature of the objects, but also upon what the actor perceives as an action possibility (even if it is not true). Thus Norman's conceptualization of affordance could be used with objects, such as a scrollbar on the computer, that do not necessarily possess directly perceivable action possibilities (e.g., because a person could perceive that the displayed computer window could be moved up and down). Although slightly different than Gibson's (1977) original conception, the Norman (1988) view is still widely accepted (Hartson, 2003; McGrenere & Ho, 2000) and maintains the original idea that inherent actions are perceived by individuals with minimal top-down processing. Perhaps strong attribute-response coupling (attributes of objects that can elicit an affordance (e.g. the perceived action possibility that an individual can scroll up and down using a scrollbar) can lead to formations of new perceivable affordances which may be termed "indirect" perception.

The direct perception approach historically differs from information processing because it downplays the importance of the contribution of higher order cognitive involvement (top-down processing). The information in the environment should be rich enough to guide actions and action possibilities of objects. Toward action selection, the study of affordances has incorporated different scenarios, from rise in step height (Warren, 1984) to natural responses to object attributes (Tucker & Ellis, 1998), as individuals try to demonstrate what affordances are and how they can be measured. However, the idea of indirect perception differs from the direct action possibilities that are scaled to anthropometrics of the body. Instead it incorporates a greater degree of top-down cognitive processes that serve to influence to the perceivable affordances of the objects. For example, Tucker and Ellis (1998) proposed that reaction times to the stimuli could be a manifestation of the action possibilities afforded by the objects. In other words, when a stimulus is oriented in such a way as to favour a response by the left hand (e.g., handle oriented to the left), the response to the stimulus by the left hand should be faster than responses with the right hand. In their study, the authors argued that this was indeed the case and that the findings were not due simply to stimulus-response compatibility (i.e., the same effect was not produced by using the index and middle finger of the right hand, thereby suggesting that the faster reaction times are due to the perceiver preferring to use the limb in the same side of space) (Tucker & Ellis, 1998). Therefore the graspable surfaces of the objects were argued to produce an affordance that primed the effector on the same side as the graspable surface.

To further expand on the concept of indirect perception of affordances, Schmidt (2007) proposed that affordances may also be derived from social contexts. Specifically, Schmidt (2007) proposed that objects may hold different social meanings for different individuals depending upon cultural differences and past, non-physical interactions. One example to illustrate this concept is receiving a gift, such as a mug. The mug carries all the physical affordances as any another mug. However, because it was given as a gift, it carries additional social meaning. That is, the person who received this mug as a gift will perceive different information from the object (i.e., the fact that it was a gift) than another who views the same mug. This is a less physical concept of affordances than that proposed originally by Gibson (1977), however it suggests that attribute-response couplings may exist that are indirectly perceived by individuals.

Another view of this indirect perception of social affordance was studied by Moll, Jordet, and Pepping (2010). In this study, the authors sought to determine how the behaviours of soccer penalty shooters affect the attitude and overall outcome of the team's performance. Specifically, when a player that scored a goal during a penalty shootout exhibit a celebratory pose (e.g., extending arm), this behaviour influenced teammates via the realization of their achievement, and thus the ultimate goal of winning. This social signal of achieving the goal was shown to affect the attitudes and the play level of the other individuals. Although no direct cause-effect relationship can be inferred, it is likely that this sort of social interaction can have some influence on the perception of attaining the goal for the other teammates. It could be argued that this indirect perception of goal attainment leads to the belief that ultimate goal is attainable by the team.

This concept of social affordances could be very important when comparing individuals with ASD and typically developing individuals, as will be highlighted in more detail following a necessary description of how movements may occur in individuals with ASD and why possible differences may arise.

Autism Spectrum Disorder

The classical diagnostic for autism, as defined by the Diagnostic and Statistical Manual for Mental Disorders (DSM IV), is impairments to social interactions, impairments to communication skills, and restricted or stereotyped patterns of behaviour, with no mention to any motor impairments (American Psychiatric Association, 2000; Baron-Cohen, 2004; Frith, 1989; Happé & Frith, 1996). While there is apparent behavioural differences when comparing individuals with ASD to control participants (typically studied by chronologically age matching and sex matching to individuals with ASD), the majority of literature to date has primarily focused on social differences, and only recently has research focused on motor differences (Glazebrook, Gonzalez, Hansen, & Elliot, 2009; Mari et al., 2003; Rinehart, Bellgrove, Tonge, Brereton, Howells-Rankin, & Bradshaw, 2006). Typically, theories of autism have generally focused on describing these impairments which are then extrapolated to any motor impairments. A brief description of some of the theories follows:

Under-Connectivity

Under-Connectivity Theory is a theory related to the neuro-anatomical function of individuals. It states that the connectivity of networks in the brain may be altered in individuals with ASD. Researchers have been trying to determine the common brain regions that are abnormal in individuals with ASD; however this has shown to be very difficult. Dawson et al. (2002) suggested that all individuals with ASD may have medial temporal lobe abnormalities and that the severity of the abnormality varies, and that this accounts for the heterogeneity of the population. However Ozonoff et al. (2004) showed evidence of frontal lobe impairments in individuals with ASD, specifically the prefrontal cortex. Other researchers have shown differences in the way brain regions are interconnected, which is widely substantiated in many experiments (Geschwind & Levitt, 2007; Lee et al., 2007; Luna et al., 2002). The temporal lobe, and more specifically, the white matter tracts in the superior temporal gyrus and temporal stem are formed abnormally as shown with diffusion tension imaging (Lee et al., 2007).

Luna et al. (2002) also demonstrated that the dorsal lateral prefrontal cortex had lower activation in individuals with ASD compared to control participants. Williams, Goldstein and Minshew (2006) also distinguished regions of underconnectivity and overconnectivity in others brain networks. They suggest that the underconnectivity would be analogous to the deficits and the overconnected regions would be analogous to the enhanced abilities. Perhaps the heterogeneity seen in ASD is associated with the variations in connections in brain structures in different individuals with ASD.

However, these imaging studies (e.g., Luna et al., 2002) showed lower activation or disconnectivity in the aforementioned regions compared to control participants, rather than "no activation." This could have profound implications because it does not suggest that individuals with ASD cannot use these areas, or not use them to their inherent potential, rather that there might be differences that exist when compared to controls. To date, there have been no studies that have shown one region of the brain that is responsible for the behaviour seen in individuals with ASD, but rather that differences in these regions may explain some of the heterogeneity seen in this population. Therefore as the name "Spectrum" suggests, there are differences that need to be considered when studying individuals with ASD.

Work from stroke patients (Doricchi, & Tumaiuolo, 2003) has demonstrated that brain lesions causing disconnectivity between regions can result in changes in functions (such as neglect). Following this line of reasoning, it seems highly plausible that disconnections between regions in the brain (e.g. such as motor cortex and supplementary motor cortex, or posterior parietal cortex) may possibly lead to the production of altered movements in the ASD population as well. Different neural connections might allow the individuals with ASD to accomplish a task (Glazebrook et al., 2009), however maybe different strategies are adopted due to different neural connections. In a study by Larson, Bastian, Donchin, Shadmehr, and Mostofsky (2008), individuals with ASD were able to learn new internal models. The individuals were exposed to force fields (via a manipulandum) and were able to learn to compensate in order to reach the targets. Even though the force field effectively changed how the target was able to be attained, individuals with ASD were able incorporate this new information into an internal model. Furthermore, individuals with ASD are able to learn new tools and adapt to new environments, despite there being an apparent abnormality in how their cerebellum is developed (Williams, Hauser, Purpura, Delong, & Swisher, 1980). This heterogeneity seen in individuals with ASD makes it difficult, if not impossible, to generalize which areas of the brain are more severely affected or what is common amongst the population.

If different structures can produce the same clinical diagnosis with different symptoms, especially when there is no clear definition for the disorder, as is the case for ASD, then trying to find a common underlying cause will be problematic. To better understand how these structures affect behaviour, it is necessary to measure and test the behavioural outcomes. If individuals with ASD can bypass higher order computation by using affordances, then we would know that the problem may not lie in perceiving the information, but instead it would suggest that the problem could lie in how individuals with ASD integrate and/or use higher order computation.

Weak Central Coherence

One of the earliest theories seeking to explain how individuals with ASD perceive their environment is Weak Central Coherence (WCC) Theory proposed by Frith (1989). This theory suggests that individuals with ASD concentrate on and perceive the smaller items that make up the "bigger picture," but have difficulties in perceiving the big picture itself. This was shown using embedded figures (Frith, 1989; Frith & Happé, 1994), which consisted of a figure that was constructed from smaller objects (e.g. a house made of triangles). However, Mottron, Burack, Iarocci, Belleville and Enns (2003) and Plaisted, Saksida, Alcantara, and Weisblatt (2003) also conducted experiments to verify Weak Central Coherence theory using different protocols. Mottron et al. (2003) used embedded figures to determine if indeed there was a deficit in global processing for individuals with ASD or if merely a preference for local processing exists instead. The procedure used by Mottron et al. (2003) differed from those of Frith (1989) as they had the groups (both ASD and controls) perform separate conditions to determine if individuals with ASD could perform as well as controls when asked to process the global picture, or if the differences arise when control individuals were asked to disengage from global processing. The results indicated that individuals with ASD perform similarly compared to the control individuals in the global processing condition. However, the individuals with ASD seemed to perform as well in both the local and global processing, and the control individuals had more difficulties in disengaging from global processing. This led Mottron et al (2003) to suggest that individuals with ASD do not have a deficit in global processing, but rather have a preference for local processing.

This finding was also consistent with that of Plaisted et al. (2003), as the authors tested Weak Central Coherence by using feature and configural trials. These trials differed by the action to be performed depending on which stimulus was given. On the feature trials, if only one colour (blue) of dots appeared on the screen, the participants were asked to depress a certain key on the keyboard ('x'). However if two different colour dots (blue and pink) appeared (configural trials), they were asked to perform a different action ('.'). The results indicated that individuals with ASD have a preference (faster reaction time) for the feature trials and that the controls had a preference (faster reaction time) for configural trials; although both groups did not differ significantly in the configural trials. This was consistent with the findings of Mottron et al. (2003), as it appeared that the individuals with ASD preferred the feature trials (can be viewed as local processing) over the configural trials (can be viewed as global processing).

Therefore it is possible that individuals with ASD may not have a deficit in global processing, but rather have a preference for local processing. Individuals with ASD might prefer to concentrate on a specific detail of the global picture which they then use to process the environment or object. In other words, although they are still able to process global information, they might view it as counter-intuitive or unnecessary. This style of processing appears to be different than the method used by typically developing individuals, who seem to demonstrate a preference for global processing in that they seem to integrate all the available information to form a global picture). This may explain some of the differences found in experiments involving individuals with ASD as it may result from the protocol used in the studies. Most of the studies involving individuals with ASD compare the performance on tasks of individuals with ASD with typically developing individuals and then make inferences about why they perform the skill differently. Perhaps valuable information about how those with ASD perform movements was being lost in the direct comparison. Individuals with ASD may be performing different skills altogether and concentrating on different factors, rather than not being able to perform the skill in the same manner as typically developing people. Therefore it is necessary to understand if individuals with ASD are indeed able to perform the same skills as typically developing individuals in the same capacity, but using different sources of information in a different manner. One method to investigate this possibility is to test how well individuals with ASD can plan and execute their movements when asked to use local and requiring less global integration to perform a skill. If indeed they have a preference for local information, they should perform the skill to the same capacity, if not better than, typically developing individuals.

Theory of Mind

How do we understand each other? The ability to place oneself in the perspective of another has been termed Theory of Mind (ToM). Believed to be a problem in ToM reasoning, a well documented deficit attributed to individuals with ASD, is the difficulty to infer the intentions of others, or empathize with them. Baron-Cohen, Leslie, and Frith (1985) proposed that individuals with ASD have difficulties with attributing mental states of another, such as beliefs, intents, desires, etc. This has been proposed to be central to social interactions (Baron-Cohen, Leslie, & Frith, 1985) as a person needs these skills when socializing with other individuals (for most typical social interactions). Understanding the perspective of another allows us to infer some of the possible reasons why people perform certain actions and what the emotional states of those individuals were at the time of their actions. One of the most widely used paradigms is the Sally-Anne task (Baron-Cohen, Leslie, & Frith, 1985). The task was designed to determine if individuals with ASD were able to place themselves in the perspective of a doll (Sally) and understand that she would not know that another doll (Anne) had transferred the marble to another location, thereby incorrectly searching for the marble in the wrong place. That is, the children with ASD were asked to determine which box Sally would look for her marble when returned from being outside (during which, Anne moved the marble to one of the boxes). The children with ASD chose the location that actually corresponded with the real location of the marble, which was argued to reflect a difficulty in ToM problem solving (Baron-Cohen et al., 1985), as they were not able to comprehend that Sally would not know where Anne hid the marble.

The Sally-Anne task has typically been studied in children, both children with ASD and controls, (Sally & Hill, 2006) and has been shown to be less impaired in adults with ASD (Ozonoff, Pennington, & Rogers, 1991). On the basis of these findings it was believed that these difficulties were alleviated by age or by learning new strategies. Ozonoff et al. (1991) suggested that individuals with ASD can use different strategies to solve ToM tasks, however when the tasks become to complex, they are no longer able to apply these strategies. For example, when individuals with ASD were required to sequence pictures to tell a story that did not require mental state attributions they performed as well as typically developing peers (Ozonoff et al., 1991). When, however, mental state attributions were required to successfully perform the task, individuals with ASD performed at significantly lower levels.

Another paradigm that has been used to study ToM employs so-called "false-belief" tasks. False-beliefs tasks are tasks where an individual is required to understand that they have gained knowledge through experience and realize that this knowledge was not known previously. An example of this is used by Pellicano (2007) where individuals were given an object (e.g., Smarties™ tube) that was filled with an unexpected object (e.g., pencils) and participants were asked "What did you think was inside the tube before you looked inside?" Individuals would have to understand that before they looked inside the tube, the most probable belief would be that the tube would be filled with Smarties™. Pellicano (2007) showed that own false-beliefs task were more difficult for children with ASD. That is, individuals with ASD would answer "pencils" more often than typically developing peers. Although Ozonoff et al. (1991) have suggested that these issues are somewhat mitigated by age, they remain problematic when especially complex situations arise.

There is also neurological evidence to suggest that ToM is altered in individuals with ASD. Lee et al. (2007) demonstrated abnormalities in the temporal lobe, and more specifically, the white matter in the superior temporal gyrus and temporal stem. This finding is consistent with Theory of Mind (ToM) deficits, as it suggests an overlap with the tempero-parietal junction, which is thought to be responsible for ToM (Saxe & Wexler, 2005). Thus it seems plausible that individuals with ASD exhibit a difficulty in understanding the perspective of another individual, however whether these difficulties extend to motor interactions with another was part of the focus of this dissertation.

Movement Impairments in Individuals with ASD

As previously mentioned, there is evidence that individuals with ASD are able to accomplish tasks with comparable accuracy to those of controls. That is, the findings of Larson et al. (2008) demonstrate that individuals with ASD were able to learn to compensate for a force field, and learn to move a pendulum to acquire a target. However, there were no analyses of the different kinematic markers in the Larson et al. (2008) experiment, and it is unknown if the quality of movements differed between groups in this task. Other researchers have shown that individuals with ASD were able to complete the task (press the button), however, the manner in which they did so differed from controls (Glazebrook et al., 2009). The findings of Glazebrook et al. (2009) show that the kinematic trajectories to the target, are more variable in the group with ASD than the controls. This could be a result of different kinematic control for the groups.

Other experiments have demonstrated different movement behaviours for individuals with ASD as well. For example, movement planning, as measured by reaction time, (Glazebrook, Elliott, & Szatmari, 2008; Rinehart et al., 2006) for individuals with ASD were slower compared with control participants (chronologically age matched and sex matched). In the Glazebrook et al. (2008) experiment, both groups (ASD and control) used the advance knowledge provided by the researchers to plan their movements. That is, if the participants were given indications about which hand or which side the target would appear, the participants demonstrated a shorter reaction time compared to when no advance knowledge was given. However, regardless of this prior information, individuals with ASD still performed slower compared to control participants. During the second experiment, Glazebrook et al. (2008) demonstrated that previous trials had a greater impact on control participants than for individuals with ASD. That is, control participants displayed a "gambler's fallacy" type of control by having a start location closer to the opposite side of the previous trial (assuming a higher probability that target at other side would be chosen). This behaviour was, however, not displayed by individuals with ASD who instead preferred choosing a more neutral position. This further illustrates a different strategy chosen by individuals with ASD to accomplish the goal of the task, which may have lead to slower reaction times.

The findings from Rinehart et al. (2006) are in accordance with the findings of Glazebrook et al. (2008). Rinehart et al. (2006) demonstrated that when the expectancy of target location was manipulated, the individuals with ASD had slower response times than control participants, but there was no interaction involving expected side of the target. Specifically, both groups behaved with similar trends when presented with different weighting on target locations (75% of time occurred on one side) or if told to acquire the target on the opposite side. This finding again suggests that individuals with ASD can perform tasks similar to control participants as they did not have difficulties in attaining that goal in the experiment (able to understand the instructions), instead they just performed more slowly when compared to controls.

The same general trend was also demonstrated for movement execution (Mari et al., 2003), as individuals with ASD were slower when compared to control individuals. This experiment demonstrated that the reach-to-grasp movements made by individuals with ASD were qualitatively different for the lower ability ASD individuals. Both the higher ability and lower ability ASD individuals performed the task (grasp the object) slower compared to the control group, however the lower ability ASD individuals time to peak aperture was delayed compared to both the control and higher ability ASD groups. Again, this suggests that individuals with ASD can perform the same task but however perform it with greater difficulty compared to control participants. One speculation may be that the differences lie in how the individuals perceived the events and may be focused on different things. Schmidt (2007) suggested that event perception is more important than timing, as individuals perceive the start and the end of an event differently from one another. Therefore it would be of interest to determine if events could be made more salient (possible explanation for longer reaction times) for individuals with ASD and adjusted to allow their strengths to be more prominent, especially when interacting with other individuals.

Perceiving the Intentions of Others

Social interactions require individuals to attend to social cues and to sometimes determine what the intentions of other people are. Social cognition is the process that allows individuals to interact with others of the same species (Adolphs, 1999). This is a complex phenomenon and is mediated by past interactions with similar situations and the understanding of social signals. However, there are other ways in which this information may allow individuals to interact with the environment or with others. There is considerable anecdotal and empirical evidence suggesting that individuals try to predict a person's movement or emotions based on previous experience and from subtle movements. For example, if the facial expression of a person is filled with fear and is running from a certain direction, than another person can infer that there is something in that direction that might not be pleasant (Frith & Frith, 2007). Research into behavioural movements of perceiving others' actions situate the hypothesized theories in a similar framework as those described above. That is, one first tries to predict the intentions (i.e. the intended motives or movements) of others based on data gathered, and on the basis of these data, then tries to construct an appropriate movement.

For example, Frith and Frith (2007) suggested that inferring the intentions of others can be accomplished by watching the movements and direction of their gaze. Also the use of gaze has been fundamental in the use of attention, as eye-tracking technology has assumed that individuals foveate on the area of interest. This is a big assumption, as attention is then linked to the foveated area and thereby direction of gaze. However, gaze patterns seem to be different for individuals with ASD (e.g., Dalton et al., 2005) which may suggest that they may not have the same patterns of attention. Another possible view is that because of the more erratic gaze patterns, perhaps this could be one possible explanation why they have a harder time perceiving the attention of others. That is, if their gaze patterns are more erratic and shorter duration (Dalton et al., 2005) then perhaps they do not spend the required time to understand the intentions of another person.

Joint Action

If individuals with ASD have difficulties in using the mirror neuron system, might this be a reason why they experience difficulties perceiving the intentions of others? One method that this notion can be studied is by a joint action paradigm, as it is suggested that the behaviour of one individual is greatly influenced by the actions and the behaviour of others. Research has shown that social signals, as Frith and Frith (2007) have suggested, are computed via two streams; signals requiring higher level computation and those that do not. Frith and Frith (2007) have argued that this is a result of evolution, as there are many signals that need to be processed quickly and without major cognitive involvement (e.g. frightful situations). However, there has been some evidence to suggest that cognitive awareness can be used to actively infer the intentions based on a stimulus-response compatibility paradigm (Olsson & Phelps, 2004). Olsson and Phelps (2004) showed that individuals could be conditioned to show signs of fear by pairing a stimulus (neutral visual stimuli) with a shock. This fear response was not seen when stimuli were masked, and the authors suggest that the association does not reach conscious awareness. This could be directly related to the ToM research, is probable that perceiving the intentions of others is mediated by the amount of cognitive awareness that is dedicated to those scenarios. Therefore, if cognitive awareness is heightened to certain objects or tasks, perhaps this could aid in perceiving the intentions of another person using these objects.

This concept of behaviour being influenced by another person is not restricted to purely social interactions. Indeed, some work has previously shown that the actions of another person can elicit the inhibition of selective attention (Welsh et al., 2005; Welsh et al., 2007). That is, when a person moved to a target, the response to that same target on consecutive trials by the other person were slower compared to responses to those targets when presented alone (Welsh et al., 2005). This Inhibition of Return (IOR) showed that movements towards the target were only affected when the other individual's intention to move to acquire this target was present, as non-biological (movements made by moving rectangle) movements did not produce the latencies (Welsh et al., 2007). These findings support the notion that individuals react differently when interacting with another. However these were individualized movements performed separately towards the same target, and not working together to achieve a common goal.

There has also been other evidence regarding joint action and the influence that another individual's movement has on the participant. For example, Marsh, Richardson, and Schmidt (2009) reviewed work that demonstrated how individuals would self-organize into a coordinated pattern relative to each other. That is, when individuals would walk side-by-side on a treadmill, they would eventually reach a coordinated pattern (e.g. in-phase). This demonstrates that the movements of one individual are affected by those of others. Other researchers have demonstrated that individuals react differently to stimuli if they are by themselves or in a group setting (Sebanz, Knoblich, Prinz, & Wascher, 2006). When the stimulus was a finger that pointed toward or away from the individual, the response to this stimulus differed if the person was responding to the stimuli without anyone beside or with another participant beside. The direction of the finger pointed was irrelevant (the experimenters did not allude to it); however it greatly influenced the motor response of individuals, as the reaction time was slower when the finger pointed to the other participant.

Therefore, both motor responses *and* emotional responses appear to be heavily influenced by the actions of another individual. This is an important concept as empathizing is very difficult for individuals with ASD. Based on this, therefore it is important to determine if joint action is also impaired to the same degree or if individuals with ASD can cooperative with others and be aware of their motor intentions.

End-State Comfort

There exists many ways in which individuals may reach and use tools, however research demonstrates that individuals typically reach and use tools in a very predictable and systematic manner. Work by Rosenbaum and Jorgensen (1992) demonstrated very nicely that individuals tend to sacrifice an initial comfortable posture in order to achieve a comfortable end posture. The participants in their experiment (Rosenbaum & Jorgensen, 1992) demonstrated that placing a bar on the shelves was dependent on how high the shelves were with the grasp (overhand, underhand) used by the participants changing depending on the task demands (height of the shelves). The proposed reason for this behaviour was that individuals engage in a cost-benefit analysis (Rosenbaum et al., 1993; Rosenbaum et al., 2001) which serves to estimate the benefits of performing the skill in a certain manner (initial awkward position) to accomplish the task in a relative comfortable posture.

Rosenbaum et al. (1993) proposed a model, the Knowledge Model, whereby central to the idea of motor planning is the idea of efficiency. That is, when planning a movement an actor has access to the coordinates of the desired object and their own starting posture. The stored postures are weighted to determine which is the most efficient for the current situation. This specific posture is then chosen and executed. The Knowledge Model postulates that the cost of the movement is derived using two terms to calculate Total Cost of the movement, Spatial Error and Travel Cost. Spatial Errors are further comprised of trying to minimize the distance of the hand from the target, while the

Travel Cost is tries to minimize the cost of moving from the starting posture to the candidate posture.

There is evidence to demonstrate that minimize the cost of the movement is accomplished by taking advantage of the musculature of the hand (Rosenbaum et al., 1990). That is, it seems that individuals prefer a neutral posture, and thereby move their hands to minimize extreme joint angles, which was supported also by the findings of Rosenbaum, van Heugten, and Caldwell (1996) as they demonstrated that movements in the middle range of motion were performed faster than those at the extreme range of motions.

This notion is important for motor planning as individuals are aware of the associated cost of their own movements. This suggests that planning a movement to grasp an object has energy consequences, however it is not well understood how these consequences are projected onto a task that requires the cooperation of two individuals to complete the objective. That is, how does one person account for the movements of the other person when they are require cooperating? Does the first individual plan their movements ahead to facilitate the movements of the second individual, even though this may require the first person to incur all of the cost of the movement (i.e., awkward posture)?

Purpose of Dissertation

The aforementioned work (Glazebrook et al., 2009; Mari et al., 2003; Rinehart et al., 2006) described the discrepancies and different behavioural strategies that arise when comparing individuals with ASD to chronologically age matched and sex matched controls. It seems evident that forcing individuals to accomplish tasks in the same manner as controls may not be the best approach to increase their level of interaction with objects and other individuals. It was, therefore, of theoretical interest to determine how individuals with ASD would use information from an object or scenario that had a high degree of action-perception coupling to accomplish a task, to determine if this could allow individuals with ASD to have performance measures similar to those of chronologically age and sex matched controls. The rationale was that individuals with ASD would be able to use the action possibilities in the objects as well as, if not better, than those of the controls to plan and execute their movements. These latent action possibilities would also presumably allow individuals (controls and individuals with ASD) to anticipate the movements of others, as the participants would infer the most probable afforded action.

The purpose of this dissertation is to progressively study the influence of objects and social scenarios with strong action-perception couplings and determine how individuals with ASD were able to use this information to successfully interact with others. Therefore, the purpose of the first study was to determine how objects with strong grasping possibilities (i.e., handles) would influence the reactions made by individuals. We hypothesized that the orientation of the handles would influence the speed in which the limbs would respond to the stimuli (Tucker & Ellis, 1998). If individuals with ASD have more difficulty in integrating sensory information as Underconnectivity Theory suggests (e.g., Dawson et al., 2002), then perhaps objects that have strong action-perception coupling would facilitate interactions with them.

In the second study we sought to expand the findings of the first study by adding a greater action component vis-à-vis 'action words' (Holt & Beilock, 2006). These action words have been shown to facilitate reactions to images that have a strong association with them (Holt & Beilock, 2006). The study was also designed to further understand how these affordances can be used to interact with others, as the perspective of another person was included to assess how action words apply to a ToM paradigm. We hypothesized that individuals with ASD would be able to use these phrases to determine what tool is required to complete the task, but would have more difficulty in determining what another individual would use to complete the action (Baron-Cohen et al., 1985).

The third study expanded the findings of the first two studies, whereby a new paradigm was designed to assess how the use of affordances may be extended to an end-state comfort/ joint-action paradigm. End state comfort literature (e.g., Rosenbaum & Jorgensen, 1993; Rosenbaum et al., 2001) hypothesized that individuals analyze graspable objects in a manner that result in the grasping motion being performed with an initial uncomfortable posture in order to have a comfortable posture as a result of object manipulation (e.g., turning a cup right-side up to pour water into). As well, the joint action literature (Welsh et al., 2005, 2007) demonstrates that movements made by an individual may be heavily influenced by the movements of another person. Therefore it was of interest to determine if controls and individuals with ASD are able to extend their own end-state comfort to a confederate's beginning state comfort when required to work in pairs to achieve the task goal. If the participants incurred the cost of the movement to facilitate the movement of the confederate, this would suggest that the individuals engaged in cooperative behaviour to accomplish the end goal. We hypothesized that controls would infer the motor intentions of the confederate and facilitate the use of the tool more than the individuals with ASD, due to the difficulties that individuals with ASD have demonstrated with ToM tasks. Therefore we hypothesized that individuals with ASD would have more difficulty in inferring the intended action of the confederate and should not aid in facilitating the movements of the confederate.

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Study One

Which Way the Handle is Pointing Might not Matter as Much as if it is Upside-Down

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Abstract

Interactions with everyday objects are mediated by the objects themselves (i.e. the shape and potential actions associated with them). However, individuals with ASD exhibit motor impairments (Glazebrook et al., 2009) and thus tend to interact with objects in a different manner. This may result from the use of different perceptual-motor resources and can imply that the perceived action possibilities of objects may be different for those with ASD. Therefore it was of theoretical interest to explore how the role of affordances would influence reaction times in individuals with ASD. A similar paradigm as Tucker and Ellis (1998) was used, as objects with handles were presented in an upright or upside-down fashion. Both controls and individuals with ASD were required to respond to the image (if it was upside-down or right-side up) without receiving explicit knowledge about the orientation of the handles. Results show that neither group demonstrated a hand advantage for the orientation of the handles (c.f. Tucker & Ellis, 1998). This implies that the orientation of the handle did not facilitate the response of the effectors used (left vs right hand).

Interaction with the environment involves a complex coordination of behaviours and movements. Much of the existing motor research has focused on how a basic movement, such as reaching for a cup of coffee in the morning, is achieved. Although general concepts explain how individuals are able to achieve this task (Kelso, 1995: Gibson, 1977; Schmidt, 1975), the precise manner in which people control their own movements is still debated by researchers. Furthermore, this seemingly simple reaching task is confounded in populations that are characterized as having motor deficits, such as the ones presented in Autism Spectrum Disorder (ASD). There is evidence to show that motor planning (Rinehart, Bellgrove, Tonge, Brereton, Howells-Rankin, & Bradshaw, 2006) and movement execution (Mari, Castiello, Marks, Marraffa, & Prior, 2003) is slower compared to control participants. However, there is evidence suggesting that the task is achieved, albeit in different manner (Glazebrook, Gonzalez, Hansen, & Elliot, 2009; Ozonoff, Pennington, & Rogers, 1991). This latter concept is important, as it is of interest to determine how movements differ between controls and participants with ASD when performed under a high action-perception coupling context.

Certain objects and settings offer a high degree of action-perception coupling, as objects presumably facilitate the user to perceive the intended use of them. Gibson (1977) proposed that latent action possibilities exist within objects and the environment, and that it depends on the ability of the user to perceive these possibilities. Essentially, tools afford actions that can be performed with them (e.g., hammer affords hammering). However, the ability to perceive these depends on the perceptual-motor resources of the observer. That is, the experience, the mental abilities, and physical capabilities of the individuals may all affect the perceivable use of the tools. Therefore the purpose of this study was to determine if individuals with ASD show similar patterns, response times and accuracy levels as control participants when responding to objects. Also it was of theoretical interest to determine if the perceptual-motor resources differ between the groups.

Some literature suggests that individuals with ASD are quite capable of completing goal-directed tasks (Glazebrook et al., 2009), but in a manner that is different from controls (Ozonoff, Pennington, & Rogers, 1991). For example, Glazebrook et al. (2009) demonstrated that when individuals with ASD reach for targets, they show no difference in end-point displacement compared to chronologically age and sex matched controls. However, when the movement kinematics are reviewed, group differences were revealed. Specifically, individuals with ASD exhibited faster reaction times when saccadic eye movements were made to their ipsilateral side compared to the contralateral side. This pattern of behaviour was not displayed by control participants, since their reaction times did not differ across hemispace. Kinematic profiles suggest that those with ASD demonstrate greater spatial variability in their movements. The authors suggested that the difficulties in coordination could be due to disconnection between regions of the brain, such as has been suggested in Underconnectivity Theory (Dawson et al., 2002).

Underconnectivity Theory has been supported in the literature, as individuals with ASD have been described as having abnormal regions in the temporal lobe (Lee et al., 2007), and disconnection of higher-order association areas (Geschwind & Levitt, 2007) and prefrontal cortex (Luna et al., 2002). It must be made clear however, that these findings from the neurological studies do not show that individuals with ASD cannot use these regions; rather they suggest that the amount of activation differs as compared to controls. Therefore it could be postulated that if stimuli to be detected by these underconnected areas were not salient enough, they could be more difficult for individuals with ASD to interpret.

One way that action-perception coupling has been studied is by using affordances. Affordances have previously been explored by testing reaction times to pictures of objects with graspable handles oriented in certain directions (Tucker & Ellis, 1998). This approach differed from other traditional ways of testing affordances, such as raiser height of stairs (Warren, 1984), and it was argued by the authors that the faster reaction times to the grasping surface by ipsilateral hand (i.e., right hand and rightward orientation of grasping handle, and left hand and leftward orientation) could be explained by the idea taht the objects afforded being grasped by that hand (Tucker & Ellis, 1998). It was further argued however, that stimulus-response compatibility was not actually responsible for the increase in reaction times, because the same reaction time advantages were not found when responses were made with the index and middle fingers of the same right hand. Other researchers (Riddoch, Edwards, Humphreys, West, & Heafield, 1998) have shown that when reaching towards an object, patients with cortico-basal degeneration usually reach with their contralateral hand compared to non-impaired controls. That is, if the cup is placed on the left side relative to the midline of the body, and the handle is facing towards the right-side, the individuals with cortico-basal degeneration reached and grasped with the right hand. This contralateral reaching was more profound when there was a strong associated action (Riddoch, Humphreys, & Edwards, 2000). Furthermore, Riddoch et al., (1998) found that when the objects were inverted, the number of contralateral reaches toward the objects was reduced (regardless of handle orientation). Therefore, it appears that not only the orientation of the handle, but the orientation of the object (right-side up or upside-down) and the level of interaction (pointing versus reaching) seem to affect the response as well.

Thus, this study sought to determine how individuals with ASD would interact with objects that were presented to them in different orientations. We hypothesised that individuals with ASD would be able to use the high perception-action coupling information and therefore demonstrate a hand advantage when the orientation of the handle was towards the corresponding hand in a manner similar to that shown by Tucker and Ellis (1998).

Method

Participants

Ten participants with Autism Spectrum Disorder (ASD; 1 female) and ten chronologically age and sex matched control participants participated in the experiment. Two males in each group were left handed and the mean chronological age was 32.1 years (SD=10.7) for the participants with ASD and 32.2 years (SD=11.1) for the control participants. Participants were remunerated $5 for their participation. All 10 participants with ASD were diagnosed by a qualified health professional (3 were diagnosed with Aspergers). All of the participants without ASD had completed high school and therefore their mental age was assumed to be similar to their chronological age. Participants with

ASD completed the Peabody Picture Picture Vocabulary Test-Revised and Raven's Progressive Matrices as a measure of verbal and nonverbal abilities respectively. Verbal age scores ranged from 9 to 33.7 years with a mean of 19.7 years (SD=7.9). IQ equivalent scores of performance on Raven's Progressive Matrices ranged from 74 to 115 with a mean 87.5 (SD=17.8). Participants with autism reported taking one or more of the following medications: *Anafranil, Rispirdal, Adovan, Divalproex, Fluoxetine, Adderal, Celexa, Carbamazepine, Citalopram, Risperidone, and Sertaline.* The experiment and procedure were approved by the McMaster University Human Ethics Board.

Apparatus

A laptop (Aspire 5630, 15.4 inch monitor) was used to deliver the stimuli through E-prime (version 1.1a) custom software. The software also recorded the participants' reaction time. All of the stimuli were coloured bitmap images with dimensions of 245 pixels x 238 pixels. Individuals were all seated comfortably in front of the laptop prior to starting (refer to Appendix 1 for list of stimuli).

Procedure

Participants sat in front of the laptop, which they adjusted prior to the commencement of the experiment. They were presented with the instructions via E-prime (version 1.1a) custom software, which where to press the 'x' button with their left hand if the image was presented up-side down and the '.' button if it was right-side up. These conditions were counter-balanced within participants (meaning 'x' represented right-side up on second half of the trials) to make sure that there were no effects for which button was pressed. All the stimuli were of objects that had a graspable handle (e.g., frying pan, coffee cup, etc). The handle was then oriented to the left or to the right side of the screen. The instructions given were to only pay attention to the vertical orientation of the objects (right-side up or upside-down) and to press the corresponding button. The participants were exposed to 4 different configurations with 92 trials for each condition for a total of 368 trials.

Data Reduction

The median time taken to press the button was recorded via E-prime software. Median scores were used because the mean scores were skewed (> 1) and, in order to protect the normality assumption for Analysis of Variance, the assumption of normality needed to be satisfied. Accuracy scores were obtained by recording the number of trials where the participants pressed the incorrect button.

Data Analysis

The stimuli were first submitted to a Cronbach's alpha and a modified Min F' (Clark, 1973; Tucker & Ellis, 1998) test to determine the reliability of the different stimuli. The min F' test was modified[1], as the experimenter had all of the available data (see Clark, 1973). The accuracy and response data were submitted to a one-way repeated measures Analysis of Variance (ANOVAs) with Group (ASD, Control) as a between participant factor and Mapping (right-side up, upside-down), Handle (left, right), and

[1] Clark (1973) conducted a Min F' test on Rubensteins et al. (1971) because they did not posses the available data to calculate a MS of an interaction, therefore they used a min and max value to approximate F ratio. Same principles were used here, but a full F ratio was calculated.

Hand (left hand, right hand) as within participant factors. Significant effects involving more than two means ($p<0.05$) were further analyzed using the Tukey HSD method for comparison of means.

Results

Reliability Scores

Cronbach's alpha revealed that the response times for the different conditions and stimuli produce a score of greater than 0.9, which suggests that the images were similar in degree of difficulty. However, the modified Min F' (22, 198) = 2.21, test revealed that two objects (a coffee mug and thermos) were responded to more slowly across groups, perhaps due to difficulties of deciphering the correct orientation (right-side up vs upside-down). Therefore, these two objects were removed from the analysis.

Accuracy Scores

The accuracy scores revealed a main effect for Group, $F(1, 18) = 5.91$, $p<0.05$, as the individuals with ASD performed that task with lower accuracy (87.9%, SE= 0.6%) compared with the control group (94.2%, SE= 0.2%). There was no other main effects or interactions (Figure 1) that reached conventional levels of significance ($p>0.106$). When the conditions for the ASD were compared to chance, all conditions were statistically better than chance ($p<0.01$). This demonstrates that the individuals with ASD were successfully able to complete the task (refer to Table 1).

Reaction Times

The analysis of reaction times revealed a main effect for Group, $F(1, 18) = 7.60$, $p<0.05$, such that the individuals with ASD (734ms, SE = 68ms) were significantly slower compared to the control group (533 ms, SE = 27ms). This finding is in accordance with the findings of Rinehart et al. (2006), wherein individuals with ASD demonstrated longer reaction times to the stimuli.

A main effect for Mapping was also revealed, $F(1,18) = 5.36$, $p<0.05$. When the response required a left hand button press for an object presented in the right-side up (LHUP) condition, the individuals pressed the required button ('x') slower (648 ms, SE = 45ms) compared with when they had to respond with the right hand (619ms, SE = 40ms) when it was right-side up (RHUP). A Mapping x Handle interaction was also revealed, $F(1, 18) = 8.41$, $p<0.05$. The post-hoc analysis revealed that when the pictures were oriented in the LHUP condition, there was no difference between when the handle was to the left (646 ms, SE = 46ms) and when the handle was to the right (651ms, SE = 45ms). There was also no significant differences in the RHUP condition when the handle was to the left (621ms, SE = 41ms) and when the handle was to the right (616ms, SE = 40ms). However the RHUP condition was responded to more quickly when the handle was to the right, compared to when than the LHUP, handle to the right condition. This effect was present regardless of handle orientation.

A Group x Mapping x Handle interaction was also revealed, $F(1, 18) = 9.40$, $p<0.05$ (Figure 2). The post-hoc analysis revealed that the ASD group was slower in all conditions compared to the control group. Within the ASD group, individuals were slower to respond in the LHUP condition compared with the RHUP condition. Specifically, in the RHUP condition, when the handle was oriented to the right (703ms, SE = 65ms), the ASD individuals were faster to respond compared to when the handle was oriented to the left (714ms, SE = 67ms). In the LHUP condition, the ASD individuals were quicker to respond when the handle was oriented to the left (753ms, SE = 73ms) than when the handle was oriented to the right (764ms, SE = 70ms). There were no differences for the control group for any of the conditions (LHUP handle left: 538ms, SE = 28ms; LHUP handle right: 537ms, SE = 28ms; RHUP handle left: 529ms, SE = 27ms; RHUP handle right: 529ms, SE = 27ms). There were no other main effects or interactions (refer to Table 2) that were found ($p > 0.094$).

Discussion

The results of this experiment demonstrate that individuals with ASD were slower at determining the correct key to press in response to visual stimuli. This is in accordance with previous research (Rinehart et al., 2006) showing that individuals with ASD have difficulties in planning movements. The results demonstrated that the individuals with ASD also had lower accuracy scores when compared to the controls. For the accuracy scores, there were no interactions or main effects for the conditions, thereby suggesting that individuals with ASD found all the conditions equally hard to discern, but had equal difficulty when compared to controls. The results, however, did demonstrate that individuals with ASD did perform better than chance, which demonstrate a similar pattern to the findings of Glazebrook et al. (2009) and Mari et al. (2003). The results thus generally suggest that although individuals with ASD were able to accomplish the task, but did so with longer reaction times.

The results also demonstrated that the individuals with ASD were quicker to respond when the handle was oriented to the right and right-side up (RHUP image, handle right). Generally, better performance were demonstrated when the stimuli were presented in the RHUP condition when compared to the LHUP mapping condition. This finding was consistent with the findings of Tucker and Ellis (1998), as individuals were faster to respond to the RHUP mapping condition as well.

The other findings, however, did not replicate those of Tucker and Ellis (1998), as there were no main effects or interactions involving the hand of response. This was puzzling, as Tucker and Ellis (1998) showed a clear advantage for hand when participants responded to the orientation of the handles with the ipsilateral hand (e.g., right hand to rightward oriented handle). It does seem logical that individuals should demonstrate an advantage when the stimuli has a protrusion that is oriented to one side, either by an ecological affordance (Tucker & Ellis, 1998) or by focusing visual attention to that side of space (Handy, Grafton, Schroff, Ketay, & Gazzaniga, 2003). If individuals do show an advantage due to visual attention, then perhaps stimuli that more effectively shift attention is required (i.e., an especially long protrusion). The stimuli in this experiment had both short and long protrusions, which may have confounded the results. Although Min F' tests were calculated, there seems to be no clear advantage for the objects with long protrusions. However, this experiment was not designed to examine the effects of long versus short protrusions, therefore this could be something of interest to determine if a difference exists when visual attention is diverted.

Furthermore, other research suggests that when an action is involved, tools afford the associated actions (Tucker & Ellis, 2001; Grèzes, Tucker, Armony, Ellis, & Passingham, 2003). Therefore the differences in this study and that of Tucker and Ellis (1998) could have been due to the specific objects used as the stimuli (Clark, 1973). Perhaps objects that are more readily used by the individuals may elicit stronger responses. Also the number of participants were much smaller in this experiment (n= 30 for Tucker & Ellis, 1998). Therefore it would be of interest to add an action associated with the image to determine how the afforded actions affect the intended actions of the perceiver.

The findings suggest that the orientation of the objects (whether the handle was facing to the right or left) did not influence the responses of the participants. Perhaps this information may have not been viewed as task relevant in this experiment. The finding that individuals with ASD responded more slowly could be due to numerous factors (e.g., perhaps disconnectivity in brain regions). This finding supports the growing literature that motor planning seems to be impaired in this population (Glazebrook et al., 2009; Rinehart et al., 2006). Perhaps further exploration would reveal why this group of individuals (individuals with ASD) experienced slower reaction times to stimuli.

The findings of this experiment also did not support the main hypothesis that individuals (both with ASD and controls) would exhibit a hand advantage for the orientation of the handle. However the results did reveal that individuals with ASD were able to correctly identify the orientation of the objects (better than chance). Perhaps individuals with ASD are able to successfully interact with tools or objects when they are required for action. Therefore, objects that have a high degree of action-perception coupling should be further explored, and the action component should be emphasized to determine how the actions associated with the objects would influence motor responses.

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Table 1.

Accuracy Scores (%) as a Function of Mapping, Horizontal Orientation, Hand and Group.

Mapping	Handle	Hand	ASD	SE	Controls	SE
LHUP	Left	Left	84	4	94	5
		Right	88	3	93	4
	Right	Left	86	3	93	5
		Right	88	3	94	5
RHUP	Left	Left	89	3	95	4
		Right	90	3	95	5
	Right	Left	89	2	95	4
		Right	89	2	95	4

Table 2.

Median Reaction Times (ms) as a Function of Mapping, Horizontal Orientation, Hand and Group.

Mapping	Horizontal Orientation	Hand	ASD	SE	Controls	SE
LHUP	Left	Left	758	234	530	92
		Right	749	241	545	91
	Right	Left	765	222	537	97
		Right	765	231	538	82
RHUP	Left	Left	714	210	534	86
		Right	715	227	523	88
	Right	Left	700	193	531	87
		Right	706	228	527	86

Figure Captions

Figure 1. **A** Accuracy scores for the individuals with ASD as a function of mapping condition, horizontal orientation and hand. **B** Accuracy scores for the controls as a function of mapping condition, horizontal orientation and hand.

Figure 2. Reaction Times as a Function of Group, Mapping Condition and Horizontal Orientation.

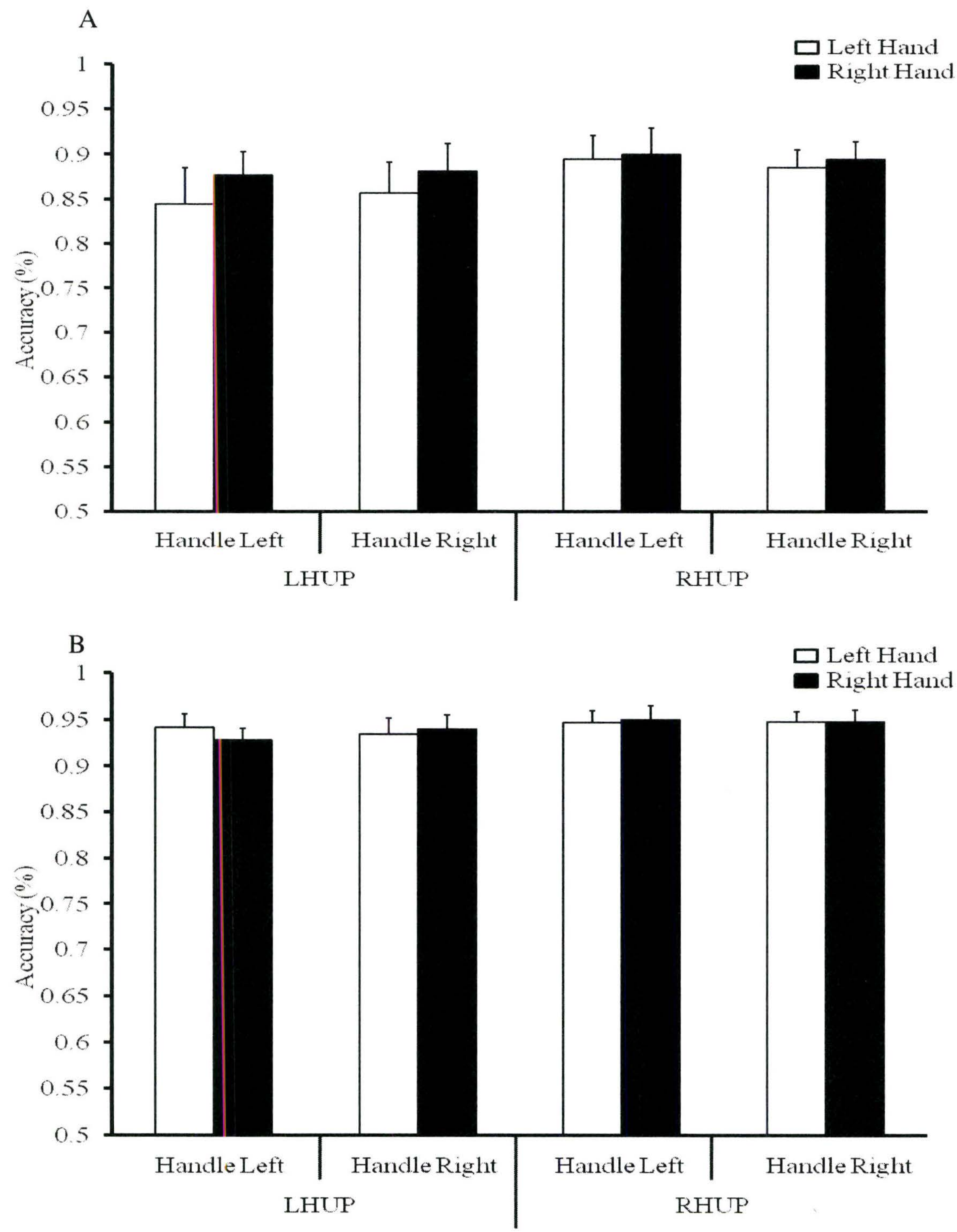
A
Left Hand
Right Hand
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Accuracy (%)
Handle Left
Handle Right
Handle Left
Handle Right
LHUP
RHUP
B
Left Hand
Right Hand
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
Accuracy (%)
Handle Left
Handle Right
Handle Left
Handle Right
LHUP
RHUP

Figure 1.

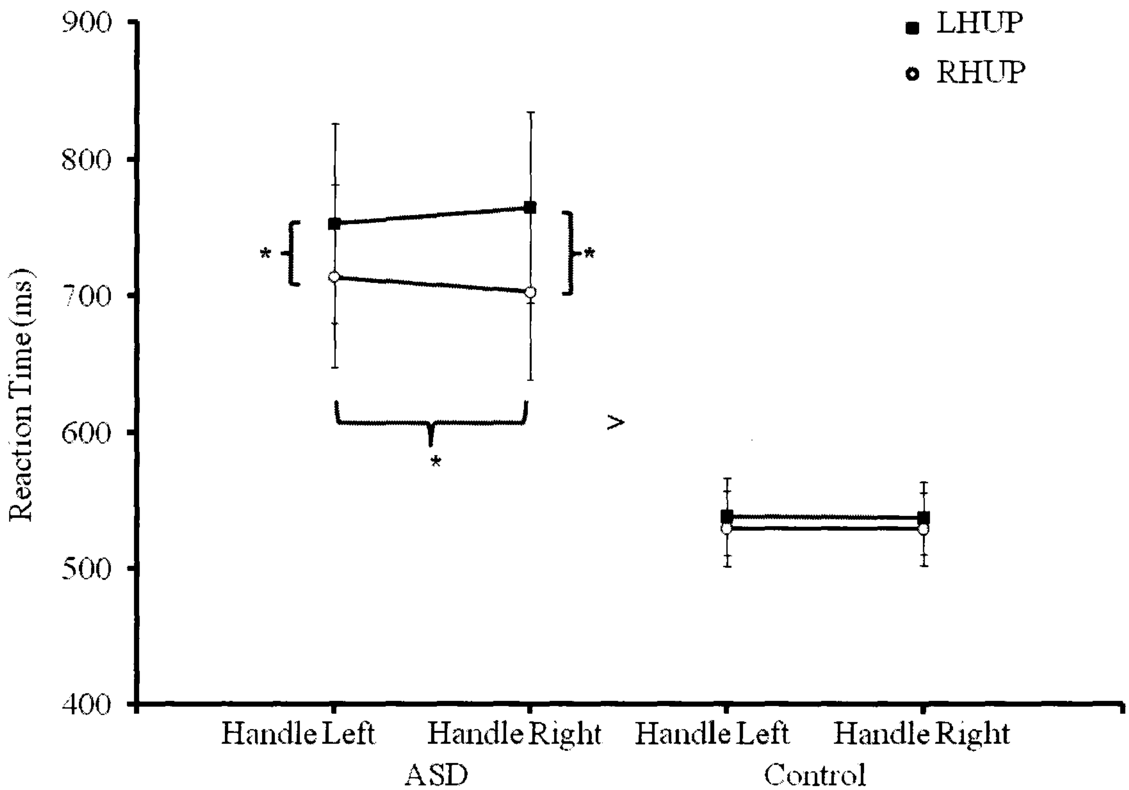
LHUP
RHUP
900
800
700
600
500
400
Reaction Time (ms)
*
*
*
>
Handle Left
Handle Right
Handle Left
Handle Right
ASD
Control

Figure 2.

Study Two

Indirectly Perceiving the Action of Another Could Alleviate Social Interactions in Individuals with Autism Spectrum Disorder

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Abstract

Several theories have been proposed to explain why social interactions can be problematic for individuals with Autism Spectrum Disorder (ASD) (e.g., Theory of Mind: Baron-Cohen, 2004). However, some motor control theories, such as the theory of social affordance (e.g., Schmidt, 2007) are underrepresented in the ASD literature. The aim of this experiment was to explore the concept of Social Affordance Theory and determine how individuals with ASD may use this information to successfully determine the intentions of an actor. Action phrases were used to portray the intentions of others, and individuals responded to images to determine what object those actors would need to fulfill their intentions. Results show that individuals with ASD demonstrated comparable levels of accuracy as chronologically age and sex matched controls, albeit slower. It could be possible that individuals with ASD could use social affordances to socialize more effectively.

Many models are used to describe differences between typically developing individuals and individuals with autism spectrum disorder (ASD). Many of these models are cognitively based and deal primarily with behavioural differences (Baron-Cohen, Leslie, & Frith, 1985; Frith, 1989). These models have been useful in describing why individuals with ASD have difficulties with social interactions; however, there are theories in motor control that are underrepresented in the ASD literature. One such theory was forwarded by Gibson (1977), who proposed that humans extract information from their environment that allows them to prepare interactions with that environment using minimal cognitive computation. This theory has also been expanded to include social affordances, whereby individuals can extract additional meanings from objects or social environments that are based not only on their physical characteristics (Schmidt, 2007). An example of this would be the receiving of a gift (e.g., a mug) from another person. This mug not only has all of the physical affordances common to a typical mug, but also carries with it a social affordance born out of the gift gesture (Schmidt, 2007). It is not well understood how this concept of social affordance is used by individuals with ASD and if it differs from what is experienced in typically developing individuals. It is possible that some of the differences observed in individuals with ASD during social interactions could be caused by difficulties in extracting relevant information from these social affordances.

There is evidence to suggest that a possible reason for the well documented social difficulties, is that individuals with ASD have trouble in understanding the perspective of others (Baron-Cohen, 2004; Baron-Cohen, Leslie, & Frith, 1985; Frith, 1989). Typically, "social contexts" refer to the inference of the mental states of others (i.e., intentions, beliefs, and desires). Recently however, evidence suggests that the observed difficulty of individuals with ASD in understanding the perspective of others may not be a matter of generalized dysfunction. Rather, individuals with ASD may strive to employ alternative strategies (compared to those engaged in by typically developing peers), in order to try to alleviate issues related to problematic social situations (Ozonoff, Pennington, & Rogers, 1991). However, although these alternative strategies may suffice in some social situations, Ozonoff et al. (1991) suggest that these strategies might begin to break down as situations become more complex. For example, when individuals with ASD were sequencing pictures to tell a story that did not require mental state attributions, they performed as well as typically developing peers. When, however, mental state attributions were required to successfully perform the task, individuals with ASD performed at significantly lower levels (Ozonoff et al., 1991). Over 25 years of research has been directed toward identifying possible causal factors for this difficulty in those with ASD. Although this research has shaped several theoretical positions, the results of specific empirical studies still remain mixed.

Theory of Mind (ToM) (Baron-Cohen, 2004; Baron-Cohen, Leslie, & Frith, 1985; Frith, 1989) suggests that when individuals with ASD are presented with circumstances in which they must confront a situation from someone else's perspective, they have both difficulty understanding what the social context is and what another person's feelings are toward the situation (Frith, 1989). For example, in a study where individuals with ASD were asked to identify how a doll would respond to a certain scenario, they had more difficulty than chronologically age and sex matched children in determining what knowledge the doll would most likely possess (Baron-Cohen et al., 1985; Sally & Hill, 2006). That is, researchers posed the question "Where would Sally look for the marble?" to participants when Sally (a doll) came back to the room. Unbeknownst to Sally, the location of the marble was changed by another doll (Anne) when Sally left the room. Results demonstrated that individuals with ASD have a harder time conceptualizing that Sally would not know that the marble was moved (by Anne) and instead would likely answer that she would look for it where it actually is (Baron-Cohen et al., 1985; Sally & Hill, 2006). This was also more recently demonstrated by Pellicano (2007), who showed that own false-beliefs tasks were more difficult for children with ASD. That is, when an object (e.g., Smarties™ tube) was filled with an unexpected object (e.g., pencils) and participants were asked "What did you think was inside the tube prior to you being shown?" individuals with ASD answered "pencils" more often than typically developing peers. These results suggest that individuals with ASD have more difficulty in tasks where they have to place themselves in an imaginative perspective, and perform the task instead with a more literal approach.

Although Ozonoff et al. (1991) have suggested that these issues are somewhat mitigated by age, they remain problematic when especially complex situations arise. Typically, studies addressing these issues have adopted an empirical framework driven largely by cognition (Baron-Cohen et al., 1985; Baron-Cohen, 2004). Specifically, these studies examine declarative responses to overtly verbal situations. Although informative in their own right, these studies have largely failed to consider the mediating effects of possible actions on the generation of specific responses. In other words, there is little existent research in the ASD literatures to inform how perception affects action and, perhaps more importantly, how action shapes perception (i.e., where actions that are associated with certain situations are dependent upon specific social and environmental contexts).

One avenue of research that explores the effects of context on action involves the use of 'action-words'. This type of research has generally shown that, in the general population, when a word or a phrase was presented to individuals prior to the presentation of an object, participants were faster to respond to those images if they were associated with an action context contained within the preceding word or phrase (Holt & Beilock, 2006; Stanfield & Zwaan, 2001). Researchers argue that this effect is due to specific action affordances provided by these words that may serve to prime the perceptual-motor system toward those actions (Holt & Beilock, 2006; Stanfield & Zwaan, 2001). Furthermore, Stanfield and Zwaan (2001) demonstrated that when individuals were presented with a phrase that required a certain orientation of an object (e.g., "John placed a pencil in the cup") participants responded to an image that facilitated this action more quickly than one that did not (e.g., a vertical cup versus a horizontal cup). In these situations, it is likely that the use of 'action words', or attributing an action performed by an actor, may be mediating any contextual ambiguities associated with objects within a given environment. If this were the case, these types of experimental arrangements would lend themselves very well to a context driven explanation of the social interaction difficulties associated with ASD.

Indeed, such an approach would be very useful in addressing several specific questions related to this social deficit issue. Are deficits in perceiving the intentions of others (Ozonoff et al., 1991) reflective of a general limitation (i.e., existent across all situations) or are they specific emotional intentions? That is, is there another way to study a ToM paradigm that is not based on verbal emotional interactions? The use of action words allow studying ToM task using a more action oriented task. If affordances are latently inherent in the environment, regardless of the actor, then this could be used by individuals with ASD to resolve some ambiguities. Therefore it is possible that individuals with ASD could use these inherent environmental cues to process possible intended actions of others by bypassing the emotional intentions of the actor. Another viable explanation for the impaired ToM skills could be proposed by Weak Central Coherence (WCC) Theory (Frith, 1989; Motrron et al., 2003; Plaisted et al., 2003). The theory states that individuals with ASD have a preference for processing local cues (smaller items that make up the bigger item) rather than the global picture. This could affect social interactions, as individuals usually convey information using more than verbal information. Perhaps integrated body language, verbal, facial expression into a global picture is viewed as counter-intuitive for individuals with ASD.

Therefore, the purpose of this experiment is to determine how written action phrases would be used by individuals with ASD. That is, individuals with ASD seem to have difficulties in understanding the perspective of others, and therefore they would have more difficulties in conceptualizing what the intended actions of an actor are. This would be evident when the individuals are exposed to the third person narrative (as this would represent a ToM task) as opposed to the first person narrative as the participants would have to place themselves in the perspective of another individual. This would lead to difficulties in choosing an appropriate object when required to fulfill the described written intended action of the actor. This difficulty would be more pronounced when the object is less congruent with the action that has to be performed, as the objects would have less direct connection between the tool and the intended action. This, however, would not be the case for when the actions where to be performed by themselves or when the object is more congruent with the intended action. The hypothesis is that participants would not need to employ a ToM perspective and that there would be a more direct connection between the tool and the intended action.

Method

Participants

Nine participants with autism spectrum disorder (ASD; 1 female) and nine age and sex matched control participants participated. Two males in each group were left handed and the mean chronological age was 32.1 years (SD=10.7) for the participants with ASD and 32.2 years (SD=11.1) for the control participants. Participants were remunerated $5 for their participation. All 9 participants with ASD were diagnosed by a qualified health professional (3 were diagnosed with Aspergers). All of the participants without ASD had completed high school and therefore their mental age was assumed to be similar to their chronological age. Participants with ASD completed the Peabody Picture Picture Vocabulary Test-Revised and Raven's Progressive Matrices as a measure of verbal and nonverbal abilities respectively. Verbal age scores ranged from 9 to 33.7

years with a mean of 19.7 years (SD=7.9). IQ equivalent scores of performance on Raven's Progressive Matrices ranged from 74 to 115 with a mean 90.5 (SD=15.8). Participants with autism reported taking one or more of the following medications: *Anafranil, Rispirdal, Adovan, Divalproex, Fluoxetine, Adderal, Carbamazepine, Citalopram, and Sertaline.* The experiment and procedure were approved by the McMaster University Human Ethics Board.

Apparatus

A laptop (Aspire 5630, 15.4 inch monitor) was used to deliver the stimuli through E-prime (version 1.1a) custom software. The software also recorded the participants' response and response times (via key press). All of the stimuli were coloured and had dimensions of 648 pixels x 244 pixels that were saved as bitmap images. Individuals were all seated comfortably in front of the laptop prior to starting (please refer to Appendix 2 for list of sentences and stimuli).

Procedure

Participants were asked to read a sentence provided on the laptop and conceptualize what idea or scenario was being presented to them. Subsequently, they were provided with two objects and were asked which one would be best suited to complete the task required by the scenario (see Figure 1). This experimental procedure was similar to previous researchers using action-words (Holt & Beilock, 2006; Stanfield & Zwaan, 2001), with the exception that in this study the object was not explicitly stated in the sentence. Participants received three practice trials with the procedure to allow them to ask any questions and to habituate them with the experiment. Participants always received two images, one that was consistent with the sentence and one that was arbitrary (to exclude random selection of images). The location of the consistent image was counterbalanced between the left and right side of the screen. The participants were asked to respond as quickly and accurately as possible to the images by depressing the 'x' button for the left image or the '.' button for the right image. No feedback was given regarding whether they had chosen the correct option.

The pictures that were consistent with the sentences were either more consistent or less consistent with the sentence given. That is, the object provided in the image could be used to immediately perform the task without first being manipulated (e.g., laptop open to surf the net). The less consistent objects had to be manipulated first in order to perform the action needed to complete the concept (e.g., laptop closed to surf the net). In addition, sometimes the image provided was of an object that was similar in principle to the one required by the task, but performed an entirely different function. An example would be the presentation of sunglasses instead of reading glasses. The last manipulation was which narrative was used to present the sentences (i.e., first person versus third person). The participants were exposed to 8 different conditions with 20 trials for each condition for a total of 160 trials (see Appendix 2 for a list of the sentences).

Data Reduction

The time taken to choose an image was recorded via E-prime software. Accuracy scores were obtained by recording the number of trials where the participants chose the arbitrary image instead of the image consistent with the sentences.

Data Analysis

The accuracy and response data were submitted to a mixed factor Analysis of Variance with Group (ASD, control) as the between participant factor and Consistency (more consistent, less consistent) and Object (same object, similar function), Narrative (first, third) and Hand (left, right) as within participant factors. Significant effects involving more than two means ($p<0.05$) were further analyzed using the Tukey HSD method for comparison.

Results

Accuracy Scores

Accuracy scores revealed a main effect for Consistency, $F(1, 16) = 8.55$, $p<0.01$, as the more consistent images were responded to more accurately (96%, SE= 1%) than the less consistent images (92%, SE= 2%). There was also a main effect for Object, $F(1, 16) = 7.3$, $p<0.05$, as the participants responded to the same object condition more accurately (95%, SE= 1%) compared with the similar function condition (92%, SE= 2%). The analysis also revealed a main effect for Narrative, $F(1, 16) = 7.05$, $p<0.05$, as the individuals responded more accurately for the third person narrative (95%, SE= 1%) compared with the first person narrative (93%, SE= 2%).

The analysis revealed an interaction between Consistency x Object, $F(1, 16) = 10.65$, $p<0.005$. The less consistent, similar function (89%, SE= 1%) condition was responded to less accurately compared to all other conditions. There was no difference between the more consistent, same object (96%, SE= 1%), more consistent, similar function (95%, SE= 2%), and less consistent, same object (95%, SE= 1%) conditions.

The analysis also revealed an Object x Narrative interaction, $F(1, 16) = 44.73$, $p<0.0001$. The similar function, first person narrative (89%, SE= 2%) was responded to less correctly compared with all other conditions. There were no differences when comparing same object, first person narrative (96%, SE= 0.8%), same object, third person narrative (94%, SE= 1%) and similar function, third person narrative (96%, SE= 1%). The analysis did not reveal any group effects, suggesting that both groups were equally accurate in determining which object was associated with the action described in the sentence, regardless of condition presented to them (Table 1).

Response Times

Response times were submitted to a Cronbach's alpha to determine the reliability across conditions. All conditions revealed an alpha level of at least 0.7, suggesting that the response times were reliable across conditions.

The analysis of response times revealed a main effect for Group, $F(1, 14) = 13.41$, $p<0.005$, with the ASD group being slower at responding (1907ms, SE= 317ms) than the typically developing control group (1023ms, SE= 169ms for control group). There was also a main effect for Consistency, $F(1, 14) = 17.31$, $p<0.005$, as the participants were faster at responding to the images that were more consistent with the sentences (1251ms, SE=131ms) than those that were less consistent (1681ms, SE= 257ms). The analysis also revealed a main effect for Object, $F(1, 14) = 23.41$, $p<0.001$, as participants were faster at responding to the images that presented same objects (1308ms, SE= 159ms) compared to the images that presented objects with similar functions (1623ms, SE= 247ms). There was also a main effect for Narrative, $F(1, 14) = 6.78$, $p<0.01$, as participants responded more quickly to the third person narrative (1385ms, SE= 195ms) compared to the first person narrative (1546ms, SE= 224ms).

The analysis also revealed a Group x Object interaction, $F(1, 14) = 5.23$, $p<0.05$. The individuals with ASD were slower to respond in the similar function condition (2140ms, SE= 374ms) compared to the control group (similar function= 1107ms, SE= 193ms; same object= 940ms, SE= 136ms), but were not significantly different in their responses to the same object (1675ms, SE= 214ms).

The analysis also revealed a Consistency x Object interaction, $F(1, 14) = 19.90$, $p<0.005$, as participants were slower to respond to images in the less consistent, similar function condition (2003ms, SE= 298ms) compared with all other conditions. The three other conditions were not different from each other: more consistent, same object (1258ms, SE= 139ms), similar function (1243ms, SE= 123ms), less consistent, same object (1358ms, SE= 176ms) conditions. This suggests that all participants had more difficulty when a less consistent image was given with an object that had a similar function. There was a trend for a Consistency x Narrative interaction, $F(1, 14) = 4.44$, $p= 0.054$, such that participants were slower to respond to images when those images were presented in the less consistent, first person condition (1807ms, SE= 275ms) compared to all other conditions. The participants were also slower to respond to images when they were presented in the less consistent, third person (1554ms, SE= 237ms) compared with the more consistent, first person (1284ms, SE= 132ms) and the more consistent, third person (1217ms, SE= 130ms) conditions (Figure 2). The more consistent conditions were not statistically different from each other. This suggests that participants had a more difficult time deciding when responding to the less consistent images, especially when the first person narrative was used.

There was also an Object x Narrative interaction was revealed, $F(1, 14) = 8.75$, $p<0.05$, such that that the participants performed significantly slower in the similar function, first person narrative condition (1766ms, SE= 267ms) compared to all other conditions. The similar function, third person narrative (1481ms, SE= 220ms) was not different when compared to the same object, first person narrative (1326ms, SE= 154ms) and the same object, third person narrative (1290ms, SE= 164ms). This suggests that both groups had more difficulty when presented with the first person narrative and the object had a similar function to the one described in the previous sentence. There was also a tendency to have more difficulties with the similar function objects compared to the same object, but the third person narrative did not reach conventional levels of significance.

An Object x Hand interaction, $F(1, 14) = 6.55$, $p<0.05$ was also revealed. All individuals were slower at responding to similar function objects (1679ms, SE= 276ms) compared to the same object (1286ms, SE= 157ms) with their left hands, but were not different compared to the similar function, right hand (1568ms, SE= 215ms). There was no difference between movements made to same object (1330ms, SE= 161ms) with the similar function objects with the right hand.

A Group x Object x Hand, $F(1, 14) = 4.64$, $p<0.05$, interaction was revealed, such that the control group revealed no differences between the conditions (same object, left hand= 925ms, SE= 143ms; same object, right hand = 955ms, SE= 129ms; similar function, left hand= 1104ms, SE= 202ms; similar function, right hand= 1110ms, SE=

187ms), whereas the individuals with ASD had slower response times overall, specifically between the similar function, left hand condition (2255ms, SE= 428ms) and the same object, left hand condition (1647ms, SE= 215ms). No statistical difference was found in the ASD group between movements made to similar function objects (2026ms, SE= 314ms) and same objects with the right hand (1704ms, SE= 230ms). This could mean that individuals with ASD make direct perception-action couplings between objects and the actions associated with them. That is, seemed to have more difficulties with objects that had similar functions but were not the same object. It could be that individuals with ASD have a direct connection between the object and the intended use. This could be a viable explanation, as individuals with ASD seem to prefer a more literal connection (e.g., MacKay & Shaw, 2004). That is, MacKay and Shaw (2004) demonstrated that individuals with ASD were better at literal meanings of words and had more difficulties with figurative language. This could be the same pattern for objects.

The analysis also revealed a Group x Narrative x Hand interaction, $F(1, 14) = 5.63$, $p<0.05$ (see Figure 2). The results demonstrated that the ASD group performed significantly more slowly than to the control group. There were no significant differences when comparing between hands within the same condition (e.g., ASD group, first person), however differences arose when comparing across conditions. The ASD group, first person narrative, right hand (2019ms, SE= 319ms) condition was significantly slower compared to the control group, first person narrative, right hand (1072ms, SE= 177ms) and the control group, third person narrative, right hand (993ms, SE= 146ms) conditions. The ASD group, third person narrative, right hand condition (1710ms, SE=

223ms) was not significantly different than the ASD group, first person narrative, right hand condition, however was significantly different compared to the control group, first and third person narratives, right hand conditions. The control group first and third person narrative, right hand conditions were not significantly different from each other. The ASD group, first person narrative, left hand condition (1979ms, SE= 353ms) was significantly different compared to the control group, first (1113ms, SE= 220ms) and third (916ms, SE= 111ms) person narratives, left hand conditions. The ASD group, third person narrative, left hand condition (1922ms, SE= 358ms) was not significantly different compared to the ASD group, first person narrative, left hand condition, but was significantly different compared to the control group, first and third person narratives, left hand conditions. There was no difference when comparing the control group, first and third person narratives, left hand conditions with each other. Comparisons involving the left and right hands across conditions were not made, as there were no logical reasons for the comparisons (e.g. ASD group, first person, left hand and control group, third person, right hand). Overall, these results suggest that the ASD group and first person narrative condition are generally slower, with no differences when comparing right and left hands within the same conditions (Figure 2).

A Consistency x Object x Narrative, $F(1, 14) = 6.37$, $p<0.05$ interaction was also revealed as the participants demonstrated slower responses in the less consistent, similar function, first person narrative condition (2239ms, SE= 318ms) compared to all other conditions (see figure 3). The less consistent, similar function, third person narrative condition (1768ms, SE= 270ms) was not significantly different compared with the less consistent, same object, third person narrative (1340ms, SE= 187ms) and the less consistent, same object, first person narrative (1375ms, SE= 168ms); however it was significantly different compared to the more consistent, similar function, third person narrative (1194ms, SE= 122ms). There was no difference when comparing the more consistent, same object, first person narrative condition (1276ms, SE= 141ms) with the more consistent, same object, third person narrative (1239ms, SE= 139ms) and more consistent, similar function, first person narrative (1292ms, SE= 124ms) conditions. This demonstrates that individuals had more difficulty responding to images containing objects that were less consistent with the sentence and had a similar function to the required object. This is consistent with an ecological perspective (Gibson, 1977), as individuals seemed to respond to objects that afforded the required actions (Holt & Beilock, 2006).

A Consistency x Object x Hand interaction, $F(1, 14) = 6.51$, $p<0.05$, revealed that the participants responded significantly slower in the less consistent, similar function conditions (left hand= 2136ms, SE= 337; right hand= 1871ms, SE= 256ms) compared to all other conditions. There were no statistical differences among the other conditions (more consistent, same object, left hand= 1247ms, SE= 140ms; more consistent, same object, right hand= 1268ms, SE= 140ms; more consistent, similar object, left hand= 1223ms, SE= 119ms; more consistent, similar object, right hand= 1264ms, SE= 128ms; less consistent, same object, left hand= 1324ms, SE= 174ms; less consistent, same object, right hand= 1391ms, SE= 181ms) and between the less consistent, similar function conditions. This finding implies that all individuals had greater difficulty, regardless of hand, when the pictures were less consistent with the sentences and the objects performed similar functions, but was not the primary intended actions that were required by the sentence (e.g., dancing shoes can be used to run).

A trend for a Group x Consistency x Object x Hand, $F(1, 14) = 7.06$, $p= 0.051$ interaction was also revealed. The analysis revealed that the individuals with ASD exhibited slower responses. Both groups seemed to have slower responses for the less consistent, similar function (ASD, left hand= 2950ms, SE= 477ms; ASD, right hand= 2429ms, SE= 372ms; control, left hand= 1322ms, SE= 253ms; control, right hand= 1313ms, SE= 220ms) conditions compared to all other conditions (ASD, more consistent, same object, left hand= 1599ms, 170ms; ASD, more consistent, same object, right hand= 1626ms, SE= 194ms; ASD, more consistent, similar function, left hand= 1560ms, SE= 144ms; ASD, more consistent, similar function, right hand= 1622ms, 147ms; ASD, less consistent, same object, left hand= 1694ms, 257ms; ASD, less consistent, same object, right hand= 1782ms, SE= 265ms; control, more consistent, same object, left hand= 895ms, SE= 139ms; control, more consistent, same object, right hand= 911ms, SE= 99ms; control, more consistent, similar function, left hand= 886ms, SE= 87ms; control, more consistent, similar function, right hand= 906ms, SE= 111ms; control, less consistent, same object, left hand= 955ms, SE= 151ms; control, less consistent, same object, right hand= 1000ms, SE= 156ms). This trend supports the other findings of the analyses, as both groups had more difficulty (slower response times) with images that were less consistent with the sentences and when they performed similar functions.

Discussion

Social interactions are very difficult for individuals with ASD, especially when empathizing with others (Baron-Cohen, 2004; Baron-Cohen et al., 1985). This has been suggested to occur, according to Theory of Mind, (ToM; Baron-Cohen et al., 1985) because individuals with ASD have difficulties in understanding the perspective of others. However, other researchers have shown that they can in fact solve ToM problems by employing different strategies (Ozonoff et al., 1991) but that these strategies often break down when the task becomes too complex.

The primary purpose of this experiment was to try to understand how these other strategies could be employed by individuals with ASD and to show that they may not necessarily have a deficit in understanding the perspective of others. It is intended to determine if they actually demonstrate a preference for focusing on the smaller items that make up the bigger picture, as would be suggested by Weak Central Coherence (WCC) Theory (Frith, 1989; Mottron et al., 2003; Plaisted et al., 2003). If individuals with ASD have a preference for concentrating on the smaller objects that constitute the bigger picture (as WCC suggests), then this could also be present when socializing with others. The experiment employed 'action-words' (Holt & Beilock, 2006; Stanfield & Zwaan, 2001) paradigm to determine if individuals with ASD could solve problems where they would have to conceptualize what object another person would need to perform an action. That is, could they put themselves in another person's situation and determine what action was required by the written task? The results of the experiment demonstrated not only could they do this, but they could do it as accurately as chronologically age and sex match controls. The only difference between the two groups was that those with ASD completed the task more slowly.

The results demonstrated that regardless of what narrative, how congruent the objects were, or whether the same object or similar functioning object was used, both groups performed similarly when comparing the accuracy scores. Although the results show that individuals with ASD were slower in deciding which object the person had to use, they still made correct responses at a level better than chance. This is not supportive to the findings shown by Frith (1989) that individuals with ASD had difficulties knowing what the other person would be thinking and how they would react to a situation where they had find where the marble would be.

Differences in the experimental protocols could perhaps explain these contradictory findings. In the current experiment individuals with ASD were much older which could explain how they are able to employ different strategies. Frith (1989) only tested adults. However, other research has shown that high functioning adults with ASD can also have problems in ToM tasks (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Happe, 1994a). In their experiment (Happe, 1994a), individuals with ASD were to recognize the mental states of an actor and match the faces to them. This could again be a difference in the findings, as the current experiment asked individuals to match an object to the intended action, not an intended feeling. Also the use of 'action-words' (Holt & Beilock, 2006; Stanfield & Zwaan, 2001) could allow individuals with ASD to bypass higher order cognitive processing by using direct perception-action objects. This approach of social affordances, could be beneficial as individuals with ASD have been reported to have brain regions which have fewer connections compared to typically developing individuals (Williams, Goldstein, & Menshew, 2006) that are theorized to be attributed to deficits in social interaction. This approach could be beneficial, as task demands could be mediated by direct environmental cues (Gibson, 1977; Schmidt, 2007).

The results demonstrate that individuals with ASD did perform more slowly compared to control individuals, which is in accordance with previous research (Mari, Castiello, Marks, Marraffa, & Prior, 2003). However, the main goal of this experiment was to show that individuals with ASD could perform this task. This would require them to conceptualize and understand what action an actor is trying to perform, via written phrases. Although the individuals with ASD were able to correctly identify the object, their response time was much slower compared to control individuals. Perhaps this is one of the reasons that social interaction is difficult for them, as it requires longer processing time to understand social contexts. That is, perhaps they may have difficulties with empathy (e.g., Baron-Cohen, 2004), but maybe not the intended action of another person as demonstrated by the accuracy scores of the current experiment.

Another possible explanation is that individuals with ASD have more difficulties in focusing on the important aspects of the interactions (whether social or environmental). That is, perhaps the manner in which individuals with ASD perform these tasks (i.e., slower) may be due to difficulties in their action capabilities. That is, perhaps previous research (Mari et al., 2003) demonstrates difficulties in their motor capabilities.

Conclusion

The purpose of this experiment was to determine if 'action-words' could be used by individuals with ASD to conceptualize a scenario where they would have to determine what object would be needed by a person to complete an action. It was hypothesized that 'action-words' would prime a participant to what objects would be required to perform the action via affordances (i.e., certain objects afford certain actions), thus facilitating the responses of the participants. The results demonstrate that individuals with ASD where able to conceptualize these scenarios, albeit more slowly than control individuals, and thereby understand the perspectives of another actor. Perhaps by using the action of a tool, the individuals with ASD are able to anticipate the intended actions of another.

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Table 1.

Accuracy Scores as a Function of Congruency, Object, Narrative, and Group.

Congruency	**Object**	**Narrative**	**ASD Score (%)**	**SE**	**Control Score (%)**	**SE**
More	Same Object	First	96	6	97	5
Consistent		Third	97	9	92	9
	Similar Function	First	93	14	92	10
		Third	98	9	99	3
Less	Same Object	First	95	9	97	5
Consistent		Third	94	7	93	6
	Similar Function	First	84	16	88	10
		Third	94	12	91	7

Figure Captions

Figure 1. Schematic of trial procedure.

Figure 2. Median response times for control and ASD groups as a function of Narrative, and Hand.

Figure 3. Median response times as a function of Consistency, Object, and Narrative.

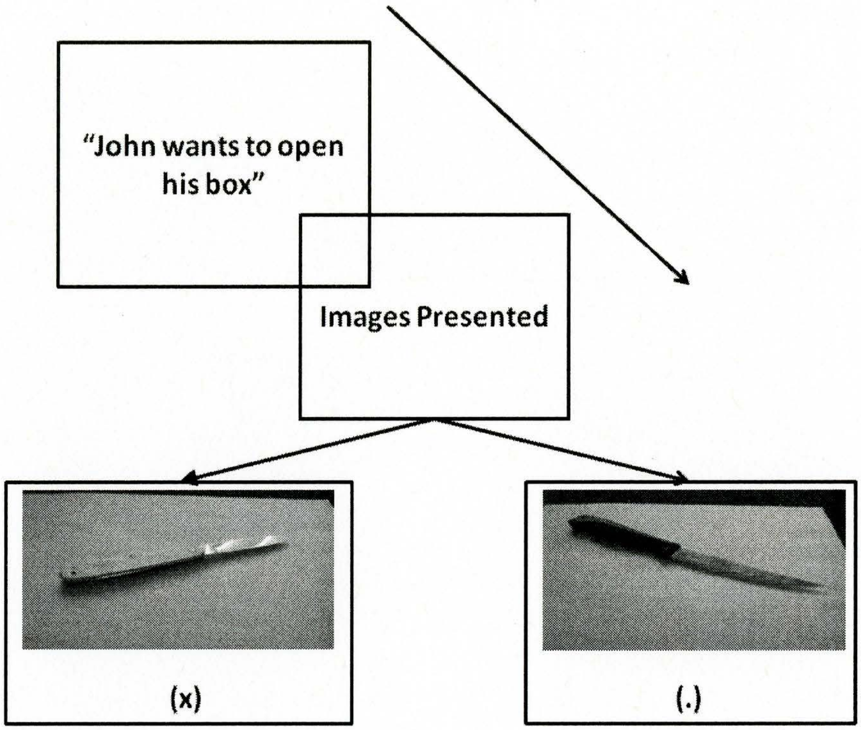

Figure 1.

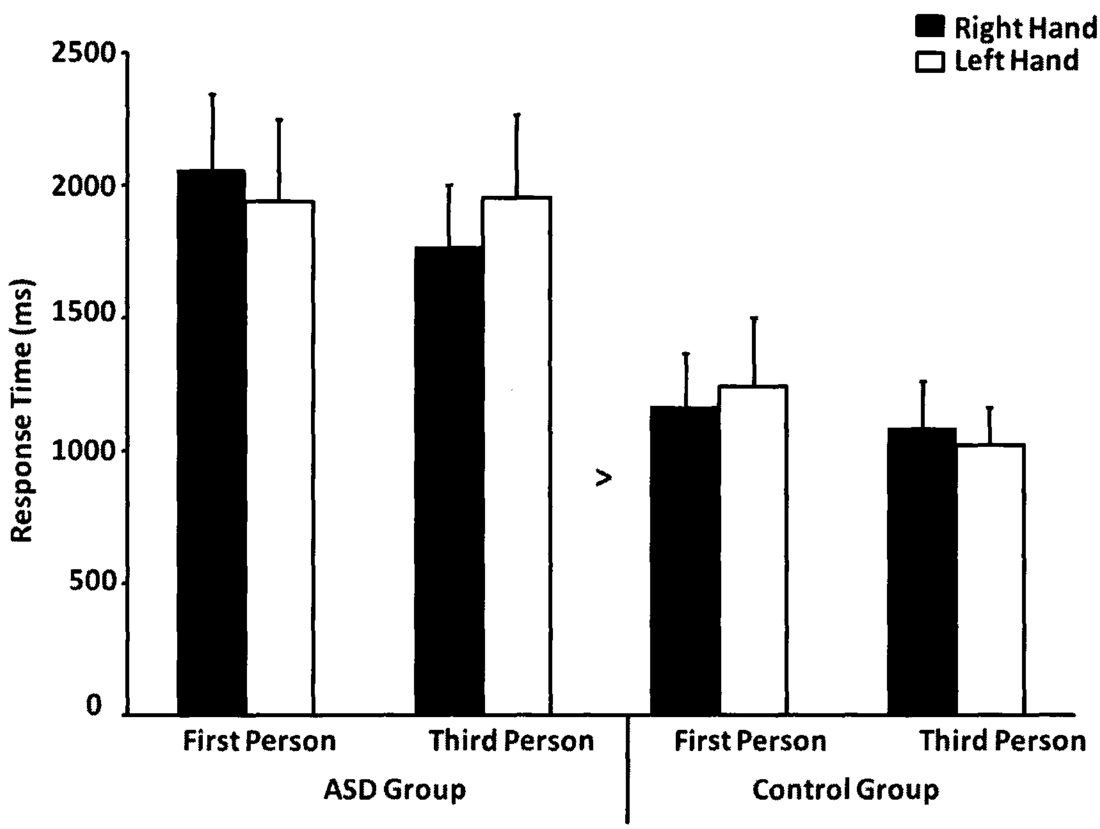
Right Hand
Left Hand
2500
2000
1500
1000
500
0
Response Time (ms)
>
First Person
Third Person
First Person
Third Person
ASD Group
Control Group

Figure 2.

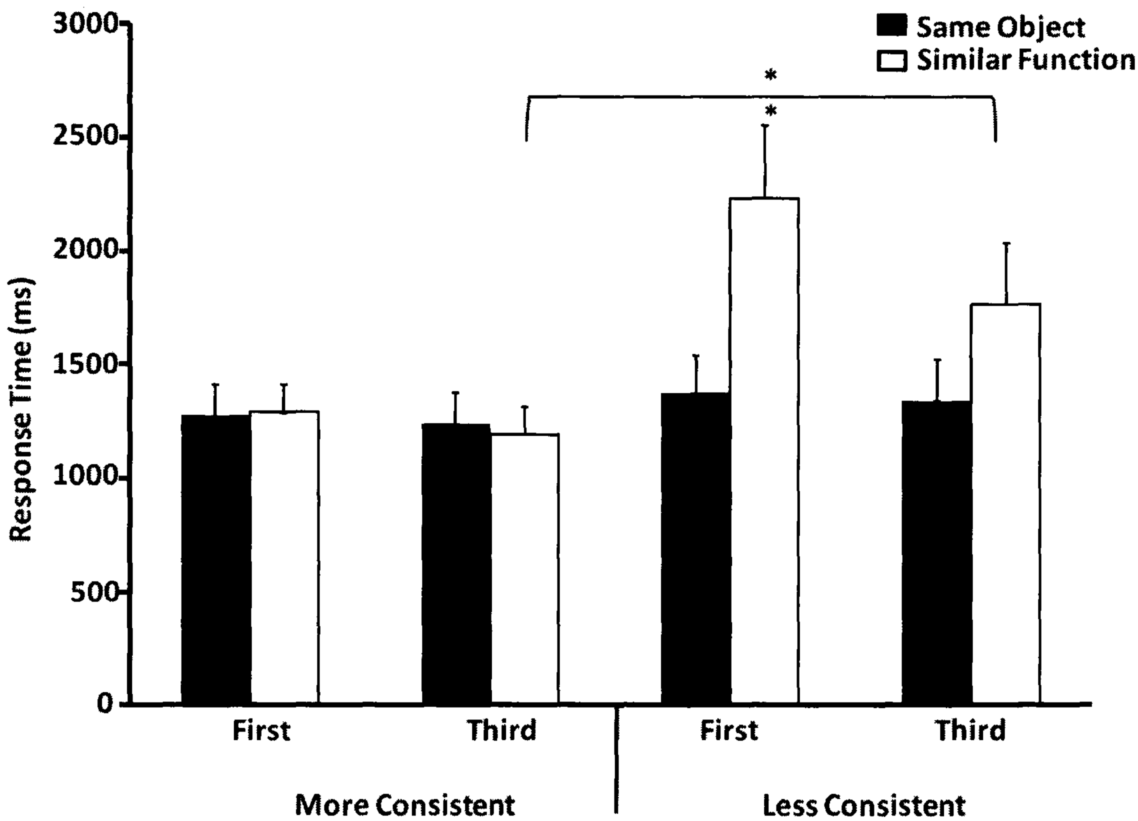
Same Object
Similar Function
*
*
3000
2500
2000
1500
1000
500
0
Response Time (ms)
First
Third
First
Third
More Consistent
Less Consistent

Figure 3.

Study Three

Motoric Interactions with Another Person: How do Individuals with Autism Spectrum Disorder Adjust?

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Abstract

When asking for a cup of coffee, performing the goal of the movement (grasping the cup) might be different for the person serving the coffee when compared to the person asking for the coffee. These types of interpersonal coordination occur on a daily basis. However this type of interaction, handing an object to another, may have profound implications for individuals with Autism Spectrum Disorder (ASD), as it may be more difficult for these individuals to anticipate how another person would use the object due to those difficulties postulated to exist in the solving of Theory of Mind problems (Baron-Cohen et al., 1985). That is, would individuals with ASD be able to anticipate what another person is going to use the tool for (by using the affordances of the tool), and thereby hand the tool in manner that would facilitate the action? Therefore the purpose of this experiment was to determine how individuals with ASD would interact with a confederate when asked to hand a tool to him/her. Theory of Mind (Baron-Cohen et al., 1985) would suggest that these individuals may have more difficulties in partaking in this joint-action paradigm. However the results demonstrated that both the controls and individuals with ASD hand the tool to the confederate in a manner that facilitated the use by the confederate (i.e., comfortable orientation for the confederate). This suggests that both the controls and individuals with ASD adopted an awkward posture to allow the confederate to have a beginning state comfort to accomplish the task in an easier manner.

Achieving goals and completing tasks are activities that occur thousands of times in a day. Such as in writing this manuscript, the authors needed to strike computer keys and successfully grasp the handle of the cups of coffee they were drinking. These types of movements involving inter-limb and inter-joint coordination patterns have been of interest to motor control researchers for over a century. However, achieving goals and completing tasks can be much more complex than just reaching for a cup of coffee and this level of complexity can be further increased by adding other individuals to the task. Motoric interpersonal skills across individuals are an important facet of life, as many individuals operate in a situation where they interact with others. Although this concept seems essential, the ways in which individuals interact with others to accomplish a task has gone relatively understudied relative to within-individual behaviours. For example, when passing a cup of coffee to another person, one needs to understand the intentions of that person (e.g., does he/she wants to drink coffee or pour it down the sink) and may take this information into consideration when interacting with them. For example, the first person may decide to orient the mug handle in a fashion that will facilitate drinking.

Such communicative interactions span both verbal and non-verbal dimensions, and it is how we represent and interpret these interactions that define to a large extent who we are as individuals. This concept of interpersonal interaction is interesting, as it introduces a level of complexity whereby one person has to understand the possible motor intentions of another from a multitude if possibilities. Such non-verbal communication is commonplace in our interactions with others. They are seen in the military (e.g., alerting troops covertly), sports (e.g., anticipating where the quarter back will throw the ball), surgical skills (e.g., team of doctors performing a complicated surgery), as well as countless everyday interactions (e.g., waving goodbye). Although some of these signs (e.g., waving goodbye) are openly understood, others may be more ambiguous (e.g., turning the head away from someone) and thus are harder to interpret (e.g., why did person turn head away?). Since interactions with others play a major role in everyday life, it is important to understand how this unspoken language is perceived, and what if anything, allows for stereotyped understanding and coordination between individuals.

This influence of another person's performance on one's own movement has been reasonably well documented in the joint action literature. For example, Welsh et al., (2005) demonstrated that when individuals perform a movement to a target, the response to the same location by the other participant was significantly slower on consecutive trials. This effect, termed Inhibition of Return (IOR), has been well documented within a single individual. However, the findings of Welsh and colleagues (2005, 2007) provides compelling evidence that what was considered to be a fairly low level neuropsychological response (e.g., Klein, 2000) can span two independent nervous systems. Others have described coordination being influenced across central nervous systems as well. Marsh, Richardson, and Schmidt (2009), for example, showed that two different individuals will self organize and reach a coordinated pattern between them. That is, the performance of the individuals will be coordinated between them when walking side-by-side on treadmill. Although there is a large body of evidence that coordination of movement across participants is dependent among the actions of another, little research has measured the coordination of individuals working together to attain a common goal.

A novel method that may be useful in assessing these interpersonal interactions is the end-state comfort paradigm. Rosenbaum and Jorgensen (1992) demonstrated that individuals exhibit an end-state comfort when they are faced with an object that they are required to manipulate. Specifically, individuals will initially sacrifice a comfortable starting posture so that they may have a comfortable posture at the end of movement, where the task goal is to be achieved (e.g., it is "easier" to manoeuvre a cup of water to the mouth when holding the cup with a comfortable grip- thumb facing upwards, than with an uncomfortable posture- thumb facing downwards). One hypothesis that describes why individuals plan movements to include end-state comfort is the Knowledge Model proposed by Rosenbaum, Engelbrecht, Bushe, and Loukopoulus (1993). They suggested that individuals undertake a cost-benefit analysis depending on the spatial and temporal demands of the tasks, which is analyzed based on initial postural constraints. This suggests that the end-state comfort of an individual is highly dependent on the initial posture (Rosenbaum et al., 1993), and that a person coordinates movement in a fashion where the cost (awkwardness) would be reduced and the benefits (comfortable posture to manipulate or achieve task goal) increased. Another model, the posture-based model (Rosenbaum et al., 2001), suggested a cost-benefit analysis; however it suggests that individuals do not minimize costs but rather contain the cost. That is, certain costs will be accepted if performance is enhanced during grasping. The finding of end-state comfort has been replicated by other researchers (Cohen & Rosenbaum, 2004; Haggard, 1998; Weigelt, Kunde, & Prinz, 2006) and has been shown to be predictable in a variety of different scenarios (Haggard, 1998) and dependent on precision (Short & Cauraugh, 1999). However, it is of theoretical interest to determine how this concept may be applied to interactions with another individual. That is, how do individuals coordinate their movements when they are required to give an object to another person?

For example, would a person incur all the cost of the movement (awkwardness of posture) to maximize the benefit of the other person (comfortable grasping posture). If so, why? If the first actor was to assume all of the movement cost in order to facilitate end state comfort for the second actor, it would suggest that the first person represents the task as one having a common goal and communicates this representation to the second person through a very specific (and personally costly) action. This coordination is paramount, as individuals are constantly participating in tasks and skills where there is a team scenario and coordination between them is critical (e.g., surgical procedures). Some tasks need to be performed efficiently in a group dynamic, where the end goal of the task may be performed by another individual.

This interpersonal coordination may also be of great interest to those interested in the study of Autism Spectrum Disorder (ASD) as it has been shown that individuals with ASD often have difficulties in interpersonal interactions (American Psychiatric Association, 2000). Baron-Cohen, Leslie, and Frith (1985) have suggested that these difficulties arise through a deficit in the ability to perceive the perspective and (action) intentions of another (Theory of Mind - ToM). For example, Baron-Cohen et al. (1985) demonstrated that individuals with ASD had difficulties in determining the would-be-actions of Sally (doll) when Anne (doll) moved a marble from one location to another. This was done by asking the individuals with ASD where they thought Sally would look for the marble when she came back into the room (after Anne had moved the marble to another location). The individuals with ASD could not comprehend why Sally would look for the marble where she had left it; instead they thought that Sally would look for the marble where it actually was (the location that Anne moved it to). Baron-Cohen et al. (1985) hypothesized that this was due to the lack of understanding of the individuals with ASD about the mental state of Sally.

Other researchers (Ozonoff, Pennington, & Rogers, 1991; Pellicano, 2007) suggest that individuals with ASD can learn to use different strategies to solve ToM tasks, but when the tasks become too complex they are no longer able to apply these strategies. For example, when individuals with ASD were required to put into sequence pictures that tell a story, and they did not require mental state attributions, the performance of the individuals with ASD was similar to their typically developing peers (Ozonoff et al., 1991). When, however, mental state attributions were required to successfully perform the task, individuals with ASD performed at significantly lower levels (Ozonoff et al., 1991). Pellicano (2007) showed that own false-beliefs task were more difficult for children with ASD as well. Specifically, Pellicano (2007) showed that when an object (e.g., Smarties™ tube) was filled with an unexpected object (e.g., pencils) and participants were asked "What did you think was inside the tube before you looked inside?" individuals with ASD would answer "pencils" more often than typically developing peers. Although Ozonoff et al. (1991) have suggested that these issues are somewhat mitigated by age, they remain problematic when complex situations arise.

The findings from Pellicano (2007) are interesting in that they suggest that individuals with ASD create a literal association between the meaning of an object and what is presented. This is further supported by the findings of MacKay and Shaw (2004), who demonstrated that figurative language was more difficult for children with ASD and performance was significantly enhanced when the language had a more literal meaning. Perhaps this literal pairing may be extended to tool use. There is an extended literature regarding the expected use of tools and their associated functions (e.g., Gibson, 1977; Roy, 1998; Wheaton & Hallett, 2007). Proponents of Direct perception theory have long argued that the "meaning" of any object (i.e., the way in which it is ultimately perceived and eventually used) is wholly dependent upon the environmental context under which the interaction takes place, the physical properties of the object itself (e.g., size, shape, texture, etc.) and the perceptual-motor resources available to the actor. Gibson (1977) later described how an individual's ability to directly perceive the actions that are available to them, using the affordance or properties latent in the action possibilities of the objects, depended on their perceptual-motor capabilities. This idea would suggest that objects themselves can often "describe" the manner of how they could be used (e.g., a hammer would afford hammering). Therefore, perhaps individuals with ASD may extract certain actions from tools when there is a direct connection between the tool and its intended function. However, they may have more difficulties when there is a more abstract connection between the function and the tool (indirect connection).

The current experiment assessed if a non-verbal, and more specifically a motor ToM task, could be solved by individuals with ASD. The current experiment borrowed from end-state comfort paradigm to determine if individuals could extend own end-state comfort to the beginning state comfort of another person. This was done by looking how tool use would affect a joint-action, whereby the second person would complete the given goal of the task and the first person would aid by passing the tool. However, there is literature to suggest that individuals with ASD have difficulties with tool use (Dziuk, Larson, Apostu, Mahone, Denckla, & Motofsky, 2007; Mostofsky, Dubey, Jerath, Jansiewicz, Goldberg & Denckla, 2006). However, a closer inspection of Motofsky et al. (2006) warrants further clarification. This is, because the errors reported in this study were categorized together. That is, there were different scores (e.g., spatial errors comprised of four different errors) that were collapsed together and compared. One of these scores was gesture to imitate, which is believed to be very difficult for individuals with ASD and their findings also report no difference in body-part-for-tool in the tool use section. This suggests that they can correctly identify what body part they need to use the tool. The results suggest that those with ASD could successfully perform this task. Therefore further clarification is needed to determine if individuals with ASD do exhibit deficits in tool use or are they able to properly use tools when performing tasks. If the individuals with ASD are able to correctly use the body-part-for-tool, then perhaps they are also able to determine how another individual would use the tool. This would clearly demonstrate that the individuals are able to use the tool appropriately.

The purpose of this study was to determine if an end-state comfort is used when interacting with others, and if this comfort is applied when passing a tool to another individual. That is, when an individual interacts with a confederate and they produce consecutive movements that share a common goal, does a person consider the posture of the other individual? If Rosenbaum et al.'s (1993, 2001) models are correct, and individuals perform a cost-benefit analysis that are aimed to contain costs on their intended movements, then the participants should minimize their own cost of the movement and not facilitate the comfort of a confederate. That is, the participants should not take into consideration the beginning state comfort of another individual. However, if the end-state comfort extends to the movements of the confederate, then the participants should adopt uncomfortable grasping behaviours in order for the end goal (performing a task) to be achieved. This would allow the confederate to employ a comfortable posture. The second goal of the experiment was to determine if individuals with ASD show similar behaviour, and perhaps anticipate the action of a confederate when they use the tool. That is, would an individual with ASD use the physical characteristics of a tool to infer the motor intentions of another?

Experiment 1

The purpose of the first experiment was to determine how individuals (with ASD and controls) use tools when they were instructed to use them by themselves. The findings of Mostofsky et al. (2006), Dziuk et al. (2007), and Hughes (1996) would suggest that the individuals with ASD would demonstrate difficulties in using tools, and therefore might not be able to complete the task. For example, Hughes (1996) found that only 28% of the individuals with ASD exhibited end-state comfort in placing a black and white bar into red and blue receptacles. That is, when the individuals with ASD were asked to place one of the bars into one of the receptacles, they used an awkward (thumb down) posture to place the correct end (black or white end) into the designated receptacle. Hughes (1996) attributed this difficulty to executing goal-directed motor acts. The findings of Glazebrook, Gonzalez, Hansen, and Elliot (2009) and Rinehart, Bellgrove, Tonge, Brereton, Howells-Rankin, and Bradshaw (2006) would also suggest that the individuals with ASD exhibit motor planning deficits. Therefore, if end state comfort is, as Rosenbaum et al. (1993, 2001) would suggest, an integral, if covert, aspect of movement planning, such planning deficits in individuals with ASD may extend to end state comfort effects. However, if an individual with ASD is able to use the affordances (Gibson, 1977) of objects, then they would be able to correctly use the tools presented to them when the tool has a strong action-perception coupling. Therefore the first experiment was designed to answer the question if individuals with ASD use tools in the same manner as controls when presented with the tools.

Method

Participants

Ten participants with autism spectrum disorder (ASD; 1 female; 2 left-handed males) and ten chronologically age and sex matched controls participated. Two males in each group were left handed and the mean chronological age was 32.7 years (SD=10.8) for the participants with ASD and 32.2 years (SD=11.1) for the participants without ASD. Participants were remunerated $5 for their participation. All 10 participants with ASD were diagnosed by a qualified health professional (3 were diagnosed with Aspergers). All of the participants without ASD had completed high school and therefore their mental age was assumed to be similar to their chronological age. Participants with ASD completed the Peabody Picture Picture Vocabulary Test-Revised and Raven's Progressive Matrices as a measure of verbal and nonverbal abilities respectively. Verbal age scores ranged from 3 to 27 years with a mean of 14 years (SD= 8.8). IQ equivalent scores of performance on Raven's Progressive Matrices ranged from 60 to 110 with a mean 84 (SD= 17). Participants with autism reported taking one or more of the following medications: *Anafranil, Rispirdal, Adovan, Divalproex, Fluoxetine, Adderall, Carbamazepine, Citalopram, and Sertraline.* The experiment and procedure were approved by the McMaster University Human Ethics Board.

Apparatus

Individuals were provided with a toy hammer (one of two different coloured), a calculator, and a stick that was painted black on one half and white on the other (this was done for instructional purposes). One of the hammers was painted with the handle white and the head black, and the other was painted in the opposite manner. Participants were only presented with one of the hammers. The colour served as a control for the instructions using the stick. The hammers consisted of a handle that was 2.1 cm in diameter and 14.8 cm in length, and hexagonal heads that were 3.2 cm in length, 5.9 cm in width and 3 cm in depth. The calculator was 8 cm wide x 15.5 cm long x 1.5 cm thick. The stick was of similar dimensions, with 2.2 cm in diameter and 18.2 cm in length. A peg board with one peg sticking up (2.3 cm in diameter, 6 cm in length) was placed in front of a participant approximately 20 cm away from the front edge of the table (approx. 67cm high). In addition, two 21.59 cm x 27.94 cm sheets of paper were place on either side of this peg board. These three objects were used to determine if individuals would be able to use physical (e.g., hammer) and cognitive (e.g., calculator) affordances to use the tools correctly. The interactions with the tools were videotaped using a Panasonic MiniDV camera which allowed the researchers to score the data post-hoc.

Procedure

Participants were seated throughout the entire procedure. The three tools (hammer, calculator, and stick) were presented to them before experimentation to allow them to become familiarized with the objects. In the experimental session participants were presented with twelve different conditions, which consisted of 3 Tools (hammer, calculator, stick) x 2 Orientation (comfortable, uncomfortable) x 2 Actions (use, place). These particular tools were used to determine how the different degrees of action-perception coupling would affect behaviour. For instance, the hammer represented the highest degree of physical contextual information (affords hammering), the calculator represented more of a symbolic representation (less physical contextual information), and the stick was a more neutral representation.

The participants were asked to use the hammer or the stick to hammer the peg or to place them on one of the two sheets of paper provided for them (of their choosing). The calculator could be used to calculate simple mathematical procedures (e.g., 53 x 11) or could be placed on the adjacent pads. The tools were either placed in a comfortable (handle facing participant) or uncomfortable initial position (handle facing away from participant) relative to the participants. This was done to determine if the participants exhibited motor planning by measuring end-state comfort (see figure 1A). After the tool was placed directly in front of the participant, the instructions of the condition were given to them (e.g., hammer the peg). For trials involving the stick, the colour end to which they were to hammer with was specified (e.g., hammer the peg with the black end). Each condition was presented six times, for a total of 72 trials for the self tasks. The conditions were blocked to allow for the development of strategies and were counter-balanced across participants.

Data Analysis

The video recordings were reviewed to determine which hand the participants used to complete the task, to determine if there was a preference for handedness. The placements of the tools by the participants were categorized into contralateral or ipsilateral hemispace[2] relative to their dominant hand. The final arm orientation was categorized into a comfortable or uncomfortable posture to determine if the individuals exhibited an end-state comfort effect. This was defined by the thumb pointing outwards, or away from the body when using the tool.

Results

Hand Used

The control participants used their dominant hand 100% of the time for all of the trials for all the tools (hammer, calculator, and stick) regardless of the condition. This demonstrates the strong preference for using their dominant hand (Pryde, Bryden & Roy, 2000). In comparison, individuals with ASD did not use their dominant hand with the

[2] Ipsilateral and contralateral space was used to account for the left handed individuals, (i.e., their ipsilateral placement would be a contralateral placement for right handed participants).

same high percentage. The individuals with ASD used their dominant hand 80% of the time for when they had to set the hammer on one of the two sheets of paper. However, when the individuals with ASD had to use the hammer to hammer the peg, they used their dominant hand on 90% of the trials (regardless of initial orientation). When the individuals with ASD set the calculator on one of the two sheets of paper, they used their dominant hand on 95% of the trials when presented with the calculator in an uncomfortable orientation and 88% when it was presented in a comfortable orientation. When the individuals with ASD were asked to use the calculator to calculate an answer, they used their dominant hand on 82% of the trials when presented with the calculator in an initial uncomfortable position, and 100% when it was presented in a comfortable position. When the individuals with ASD set the stick on one of the two sheets of paper, they used their dominant hand on 80% of the trials when the stick was presented in an initial uncomfortable orientation, and 78% when presented in an initial comfortable orientation. When the individuals with ASD were required to use the stick to hammer the peg, they used their dominant hand 85% of the trials (regardless of initial orientation). This would suggest that their preference for hand dominance may not be as high as controls. This may result from different lateralization connections in the brain of individuals with ASD (Escalante-Mead, Minshew, & Sweeney, 2004). That is, they may not have a strong preference for the use of a hand (see Table 1).

Side Placed

When the control participants were asked to place the tool on one of two sheets, they chose to place the tool on the contralateral side (with respect to their dominant hand) on 21% of the trials for the hammer when presented in an initial uncomfortable position and on 17% of the trials when presented in a comfortable position. They chose to place the calculator on the contralateral side 12% of the trials when presented in an initial uncomfortable position and 10% when presented with an initial comfortable position. Finally, they chose to place the stick on their contralateral side 19% of the trials (regardless of initial orientation). In other words, control individuals chose a movement that did not require reaching to contralateral hemispace and opted for ipsilateral movement more often. When the individuals with ASD were asked to place the tools on one of the two sheets, they chose to place the tools almost equally across both sides (53% for hammer with initial uncomfortable position; 57% for hammer with initial comfortable position; 55% for calculator with initial uncomfortable position; 42% for calculator with initial comfortable position; 53% for stick regardless of initial orientation). This would suggest that they preferred to utilize both sides equally instead of comfortably reaching for the ipsilateral side like the controls. This finding suggests that the economy of the movement (more efficient to remain on the same hemisphere) may not be the highest priority for individuals with ASD (see Table 2).

End State Comfort

The control participants demonstrated end state comfort on 100% of the trials for all of the tools (with one exception, calculator presented in an uncomfortable initial orientation and used to calculate an answer to a question). Thesê results were consistent for all conditions (comfortable and uncomfortable presentation of tools). This pattern of behaviour suggests that these individuals were able to plan their motor actions in advance by choosing a posture that would result in a comfortable end state (Rosenbaum & Jorgensen, 1992). The individuals with ASD demonstrated a high degree of end state comfort as well, as demonstrated the following results (Table 3): 100% end state comfort for the hammer was to be used to hammer (regardless of orientation); 90% when hammer was to be placed on one of the two sheets of paper (regardless of orientation); 100% for calculator when placed in comfortable orientation and asked to calculate; 90% when placed in comfortable position and asked to place on one of two sheets of paper; 53% when placed uncomfortably and asked to use the calculator to calculate; 98% when asked to place the calculator on one of two sheets of paper and presented in an uncomfortable position; 90% when asked to place stick on one of two sheets of paper and presented in a uncomfortable orientation; 93% when asked to place stick on one of two sheets of paper and presented in a comfortable orientation; 100% for stick when asked to be used to hammer (regardless of initial orientation). These results suggest that the individuals with ASD demonstrated appropriate motor planning for this task. Initially, this does not support the findings of Glazebrook et al. (2009) and Rinehart et al. (2006).

Discussion

The results of experiment one demonstrated that the controls and individuals with ASD exhibit end-state comfort (Rosenbaum & Jorgensen, 1992) and were able to complete the tasks. The fact that individuals with ASD were able to use the tools seem at odds with the findings of Mostofsky et al. (2006), Dziuk et al. (2007) and Hughes (1996). However, there are methodological differences that may explain the discrepancies of these findings, as Mostofsky et al. (2006) and Dziuk et al. (2007) included a battery of tasks for their measures. This battery included measures such as gesture to imitate, which may have suggested that these individuals are not able to use tools. However it could be the case that when a concrete task is given, such as hammering a peg, the individuals with ASD are able to use the physical characteristics of the tool to aid in determining how the tool should be used.

The findings that individuals with ASD also demonstrated the ability to plan their motor actions (as measured by end-state comfort) do not entirely support the findings of Glazebrook et al. (2009), Hughes (1996) and Rinehart et al. (2006). The findings of Glazebrook et al. (2009) and Rinehart et al. (2006) suggest that individuals with ASD should exhibit deficits in motor planning. However the results of the current study clearly demonstrate that they were able to use end-state comfort and thereby exhibit intact motor planning (Rosenbaum & Jorgensen, 1992). These discrepancies could be a result of the measures taken by the different researchers, as the findings of Glazebrook et al. (2009) and Rinehart et al. (2006) measured reaction time and the current experiment measured end-state comfort. It is important to note that the findings also do demonstrate that individuals with ASD can complete tasks (Glazebrook et al., 2009). Therefore it could be the case that individuals with ASD need longer preparation time, but could pre-plan their motor actions to complete the task. Reaction time was not measured due to the technical limitations of the experiment.

The findings of Hughes (1996) suggest that individuals with ASD should have difficulty in displaying end-state comfort. While the findings of the current experiment do not entirely support this, as the individuals with ASD demonstrate end-state comfort in many trials. Perhaps this can be attributed to the high degree of action-perception coupling of the objects with the task (i.e., hammer affords hammering). However, it should also be noted that the individuals with ASD did show a high percentage of end-state comfort when using the stick which may be a function of the action performed. Perhaps the individuals in this experiment have more experience performing this action (hammering) which may result in a higher percentage of end-state comfort.

It could have also been the strong literal association between the action of the tool and the desired action (e.g., hammer for hammering) that helped plan the movements used by with ASD. This strong association may then perhaps be used to infer the motor intentions of another.

Experiment 2

The perception of the intention of another has been termed Theory of Mind (ToM, Baron-Cohen, Leslie, & Frith, 1985), which allows individuals to form meaningful social interactions by being able to perceive the perspective of another individual. Although individuals constantly display a ToM, it is not evident that this finding applies to end-state comfort for another individual. That is, will an individual be able to infer the motor intentions of another and facilitate the use of a tool by handing the tool in a manner that optimizes initial use by a confederate? Or worded more succinctly, can an individual extend their end-state comfort to be applied to another's beginning state comfort? This has theoretical interests, as it would require the first person (participant) to incur all the cost of the movement (awkward posture) to allow the other person (confederate) an initial comfortable grasp to complete the task. Furthermore, the application to individuals ASD would allow a direct comparison to a population that is known to have great difficulties in perceiving the intentions of others (Baron-Cohen et al., 1991).

While it has been demonstrated that higher order ToM tasks are difficult for individuals with ASD to solve (Ozonoff et al., 1991), this is a concept that has traditionally been explored by asking individuals with ASD to imagine the actions of another under hypothetical situations, such as the Sally-Anne task (Baron-Cohen et al., 1985). However it is not well understood how these individuals may solve similar problems when they are asked to solve motor intentions of another when physically interacting with another person. That is, if the individuals know the task that someone else will perform, do they take this into consideration when planning their own movements?

There are studies that have demonstrated an inhibition of return to target locations in two participants working together in a coordinated manner (Welsh et al., 2005). However, this research did not focused on how two individuals worked together in a task when the individuals coordinated movements to achieve common goal, and how the first individual would account for the actions of the other person. Therefore, the purpose of the second experiment was to determine how both control individuals and individuals with ASD would account for the beginning state comfort of another person when asked to pass a tool. We hypothesized that control individuals would show an ability to understand the beginning state of the confederate and pass the tool to minimize the confederates movements before using the tool. However, we hypothesized that individuals with ASD would show difficulties with this, and would not pass the tool in an orientation that would allow the confederate to adopt a beginning state comfort, as it would require a ToM skill.

Method

Participants

The same participants in experiment 1 participated in experiment 2, during the same session.

Apparatus

The apparatus and set up used in experiment 2 was identical to the apparatus in experiment 1.

Procedure

Participants were told that they were going to be working with someone (confederate) to complete the tasks. The experimenters mentioned at the beginning of the task that the confederate was right-handed and that the participants should make the task *as easily and efficient for the confederate as possible.* Twenty-four different conditions were included; 3 Tool (hammer, calculator, stick) x 2 Participant Actions (place tool, hand tool) x 2 Orientation (comfortable, uncomfortable) x 2 Confederate Action (use, place). The participants performed 6 trials per condition for a total of 216 trials. Participants were always given prior knowledge of which condition was to be performed for the upcoming trial.

The participant was asked to either to place the tool on one of the two sheets of paper provided or hand the tool to the confederate. When the participant placed the tool, on certain trials the confederate did not use the tool (which served to determine how the presence of a confederate influenced placement) and on others he used the tool for the intended purpose (hammer the peg or calculate the answer). This was with the condition predetermined by the experimenter, who then gave the instructions to the participant and the confederate prior to starting the trial. The difference in these instructions and conditions allowed comparison of how the participants would behave when handing a tool to the confederate when the tool was required to be used for the intended purpose and when the tool was just going to be simply placed aside. The tool was also placed in a comfortable or an uncomfortable orientation relative to the participant to determine how the movements were planned regarding end-state comfort of the participant (see Figure 1B).

Data Analysis

The video recordings were reviewed to determine which hand the participant used, and to determine if a preference for handedness was also noted. The placement of the tool by the participant was categorized into contralateral or ipsilateral hemispace[3] relative to his or her dominant hand. The final arm orientation was categorized into a comfortable or uncomfortable posture to determine if the participant exhibited end-state comfort. In addition, beginning state comfort was measured for the tasks that involved a confederate, to determine if the confederate was afforded a comfortable or an uncomfortable initial grasp.

[3] The terms ipsilateral and contralateral space were used to account for the left handed individuals (i.e., their ipsilateral placement would be a contralateral placement for right handed participants).

Results

Hand Used

The control participants used their dominant hand on 100% of the trials for most of the conditions, with two exceptions: 1) on 10% of trials control participants handed the stick with their non-dominant hand when the stick was initially in an uncomfortable orientation and the confederate would be using it to hammer; 2) on 12% of trials where the confederate was going to use the calculator, control participants used their non-dominant hand, regardless of initial orientation. This is in accordance with the findings of Pryde et al. (2000) as they demonstrated that individuals prefer using dominant hand for grasping tools, more so when tool use was required.

The individuals with ASD used their dominant hand on 88% of the trials when handing the hammer to the confederate and the confederate was to place the hammer on one of the two sheets of paper (regardless of initial orientation). Individuals with ASD used their dominant hand on 80% of the trials when handing the hammer and the confederate was to hammer the peg (regardless of initial orientation).

When handing the calculator to the confederate, the individuals with ASD chose to use their dominant hand on 100% of the trials regardless of the condition. Individuals with ASD also chose to use their dominant hand on 90% of the trials when handing the stick to the confederate, regardless of the condition. The results differed when the individuals with ASD were to place the tools on one of the two sheets of paper. The individuals with ASD chose to use their dominant hand on 85% of the trials when they had to place the hammer on one of the two sheets of paper and the confederate was not going to use the hammer, for the uncomfortable initial orientation, and 83% for the comfortable initial orientation. When the confederate was going to use the hammer to hammer the peg, the individuals with ASD chose to use their dominant hand on 88% of the trials when the hammer was placed in an uncomfortable initial position and 80% when placed in a comfortable initial position.

When the individuals with ASD were presented with the calculator in an uncomfortable initial position and were asked to place the calculator on one of the two sheets of paper, they chose to use their dominant hand on 100% of the trials (regardless of the action of the confederate). However, when the calculator was presented in a comfortable initial orientation, the individuals with ASD used their dominant hand on 97% of the trials when the confederate was not going to use the calculator, and 98% of the trials when the confederate was going to use the calculator to calculate the answer. The individuals with ASD chose to use their dominant hand on 85% of the trials when they were asked to place the stick on one of the two sheets of paper, and the confederate was not going to use it (regardless of initial orientation). However, when the confederate was going to use the stick to hammer the peg, the individuals with ASD used their dominant hand on 90% of the trials when the stick was presented in an initial uncomfortable orientation and on 80% of the trials when it was provided in a comfortable initial orientation. This suggests that individuals with ASD do not have the same strong preference for using their dominant hand to complete tasks (see Table 4).

Side Placed

When the control participants were asked to place the tool on one of the two sheets so that the confederate could use the tool for its intended purpose, they chose to place the tool on their contralateral (ipsilateral for confederate) side nearly 100% of the time for all of the tools (98% for the hammer regardless of initial orientation; 100% for the calculator when presented with an initially uncomfortable orientation and 96% when comfortable initial orientation; 96% for stick with an initially uncomfortable orientation and 98% with an initially comfortable orientation). When the confederate did not use the tool, they placed the tool on their contralateral side nearly 25% of the time (29% for the hammer when presented with an initially uncomfortable orientation; 25% for the hammer when presented with an initially comfortable orientation; 23% for the calculator when presented with an initially comfortable orientation; 27% for the calculator when presented with an initially uncomfortable orientation; 21% for the stick when presented with an initially uncomfortable orientation; 29% for the stick when presented with an initially comfortable orientation). This suggests that the control participants placed the tool only on the contralateral side when the confederate was to use the tool, as placing the tool on this side would inconvenience the participant.

The individuals with ASD chose to place the hammer on their contralateral side on 92% of the trials when the confederate was going to hammer the peg (regardless of the initial orientation). When the confederate was not going to use the hammer, the individuals with ASD placed the hammer on the contralateral sheet of paper on 48% of the trials when presented in an initial uncomfortable orientation and 57% when presented in an initial comfortable orientation. When the calculator was used, the individuals with ASD chose to place the calculator on the contralateral sheet of paper on 52% of the trials when they were provided with an initial uncomfortable orientation and the confederate was going to use it to calculate the answer, and 63% when presented with an initial comfortable orientation. When the confederate was not going to use the calculator, the individuals with ASD placed the calculator on the contralateral sheet of paper on 47% of the trials when presented in an uncomfortable initial orientation, and on 57% of the trials when presented in a comfortable initial orientation. Finally, when the stick was used, individuals with ASD placed the stick on the contralateral sheet of paper on 78% of the trials when the confederate was going to use the stick to hammer the peg and presented in an initial uncomfortable orientation and on 87% of the trials when presented with an initial comfortable orientation. The individuals with ASD chose to place the calculator on the contralateral sheet of paper on 55% of the trials when the confederate was not going to use the calculator (regardless of the initial orientation). The high degree of placement on the contralateral hemispace sheet of paper (see Table 5) was due to the intentions of the confederate (i.e. how the confederate was going to use the tool).

End State Comfort

The control participants exhibited end state comfort on nearly 100% of the trials, regardless if asked to place the tool or hand the tool to the confederate, except for the following conditions: 98% of the trials when handing the hammer to the confederate when the confederate used it to hammer the peg and presented with an initial comfortable orientation; 96% for the calculator when handing the calculator to the confederate when going to use to calculate the answer and placed in a initial comfortable orientation; 98% for the stick when handing the stick to the confederate to hammer the peg with, and placed in a uncomfortable orientation; 98% for the hammer when asked to place the hammer on one of the two sheets of paper and placed in an initial comfortable orientation, regardless of action of confederate. This suggests that the participants were able to plan for their own comfort at the end of the movement for most of the trials (i.e., participants did not adopt a new strategy of uncomfortable end-states in order to accommodate the goals of the confederate).

The individuals with ASD demonstrated a high degree of end state comfort for all conditions as well (90% when handed the hammer to the confederates and that was presented with an initial uncomfortable orientation, regardless of use by confederate; 83% for the hammer when handed the hammer to the confederate which was placed with an initial comfortable orientation, and the confederate placed the hammer on one of the two sheets of paper and 73% for when confederate used the hammer to hammer the peg; 100% for the calculator when handed the calculator to the confederate and presented the calculator with an initial uncomfortable orientation, regardless of use by the confederate; 90% for when handed the calculator to the confederate, presented with initial comfortable orientation and the confederate placed the calculator on one of the two sheets of paper; 77% for when handed the calculator to the confederate, presented with initial comfortable orientation and the confederate used it to calculate the answer; 92% when handed the stick to the confederate, presented in an initial uncomfortable orientation and the confederate set it on one of the two sheets of paper, and 97% when used it to hammer the peg; 87% when handed the stick to the confederate, presented in an initial comfortable orientation and the confederate set it on one of the two sheets of paper, and 65% when they used it to hammer the peg; 90% when placed the hammer on one of the two sheets of paper, and the confederate did not use the hammer, regardless of initial orientation; 75% when placed the hammer on one of the two sheets of paper, with an initial uncomfortable orientation, and the confederate used the hammer to hammer the peg and 80% when placed with an initial comfortable orientation; 90% when placed the calculator on one of the two sheets of paper, with an uncomfortable initial orientation, and the confederate did not use the calculator and 98% when the confederate used the calculator to calculate the answer; 97% when placed the calculator on one of the two sheets of paper, with an initial comfortable orientation, and the confederate did not use the calculator and 70% when the confederate used the calculator to calculate the answer; 97% when placed the stick and initially presented with an uncomfortable orientation and the confederate did not use the stick, and 95% when the confederate used the stick to hammer the peg; 98% when placed the stick and presented with an initial comfortable orientation and the confederate did not use the stick, and 68% when the confederate used the stick to hammer the peg). This suggests that the individuals with ASD were also able to plan their motor movements in advance (terminate their own movement with end-state comfort), even when it required handing the tool to the confederate (see Table 6). This again shows differences compared to the findings of Glazebrook et al. (2009) and Rinehart et al. (2006). However the findings are in accordance with the findings of Rosenbaum and Jorgensen (1992).

Beginning State Comfort for Confederate

The condition of most interest was when the participants were presented with the tool in a comfortable orientation relative to them (would require the participant to either adopt a beginning or end state discomfort, if the participants allowed the confederate to adopt a beginning state comfort). As such, when the tool was presented in a comfortable orientation and were asked to hand the tool, so the confederate may use it for the intended purpose, the control individuals handed the tools in a manner that facilitated the beginning state comfort for the confederate on 100% of the trials. Thus, the confederate did not need to re-orient the tool in order to adopt a comfortable posture before using it (i.e., turn the tool around). However, when the control participants were asked to hand the tools and the confederate who was not going to use it for the intended purpose the controls handed the hammer a manner that facilitated the confederate beginning state comfort on 63%, the stick 10%, and the calculator 25% of the rials (see Figure 2). This suggests that the control participants were concerned with the intended action with the tool, and were not just coincidentally handing a tool to the confederates in a manner that facilitated the tool's use.

Furthermore, when the controls were asked to place the tool on one of the two sheets of paper, and the confederate was going to use the tool, the participants placed the tool which gave the confederates a beginning state comfort on 100% of the trials. Again, this pattern was greatly reduced when the confederates were not going to use the tools for the intended purpose; such that the percentages of trials where the tools were placed in an orientation that facilitated beginning state comfort for the confederate was 0%, 13% and

0% for the hammer, calculator and stick, respectively. This pattern of behaviour supports the hypothesis that the control participants take into account the intended actions of the confederate when the task was to help this individual complete a task. In addition, the greater percentage of comfortable placement for the hammer versus the stick and the calculator suggests that the physical characteristics of the hammer (its affordance for hammering) influenced how participants chose to interact with the object even when hammering was not the intended action.

During the condition when the participants with ASD were asked to hand the tools to the confederate, so the confederate may use the tools for the intended purpose, the findings demonstrated that the participants with ASD orientated the tools in a manner that allowed the confederates to adopt a comfortable posture. Furthermore, this was done to a higher degree for all three tools as compared to when the confederate did not use the tools for their intended purpose (Figure 2). Specifically, the participants with ASD gave the tools to the confederate in an orientation that would be initially most comfortable (for the confederate) 65% of the time for the hammer, 55% of the time for the calculator, and 73% of the time for the stick. The percentages for when the when the participants with ASD gave the tools were higher compared with the condition where the confederate placed the tools down (27%, 22%, and 23% respectively). The individual performances were plotted to illustrate the differences between the individuals with ASD (Figure 3A and 4A), as they all responded differently to the tasks. This demonstrated that some of the individuals with ASD were able to hand the tools in a manner which benefited the confederate, although it meant inconveniencing their posture (i.e., either beginning state or end state discomfort). The trial-by-trial graphs for these conditions show that the individuals with ASD had variable performances (figure 3B and 4B) and that there were no recognizable strategies developed by these participants (except participant 3 for the hammer, the individual started turning the hammer around on the second trial and continued for the rest of the trials).

When the participants with ASD were asked to place the tools on one of the two sheets of paper, the percentage of occurrences of the tools being placed in a comfortable orientation for the confederate were 48% for the hammer, 53% for the calculator, and 68% for the stick when the confederate was going to use the tools for its intended purposes. This would suggest that the individuals with ASD demonstrated less concern for the confederate when the tools were placed on one of the two sheets of paper instead of directly handing it to them. This could be due to the less direct interaction between the confederate and the participants with ASD. The occurrence of placing the tool in an orientation that was comfortable for the confederate was reduced greatly when the confederate was not going to use the tool (12% for hammer, 10% for calculator, 2% for stick) as there was little reason for the participants to incur the cost of an awkward posture in this condition (see Table 7).

Discussion

The results of experiment 2 suggest that both the controls and individuals with ASD were able to anticipate the motor intentions of the confederate. This was demonstrated by the participants maximizing the beginning state comfort of the confederate when the tools were handed to them. That is, the participants often turned the tool in such a manner that the confederates were able to use the tool without further manipulation, even when it required the participants to adopt an uncomfortable posture. This finding is novel, as it demonstrates that both the controls and individuals with ASD are able to extend their end-state comfort to another individual and incur the cost of the movement (assuming an awkward posture to facilitate the end goal for the confederates). This extends the literature of end-state comfort, as the individuals may be adopting the final end goal of the task as being when the confederate performs the required task and not the end of their own (participant's) movement. This may explain why individuals are incurring the cost of the movement to aid the confederate in performing the task.

The results also appear contrary to the findings of Theory of Mind (Baron-Cohen et al., 1985) but support the findings of Ozonoff et al. (1991). Ozonoff et al. (1991) suggest that individuals with ASD are able to solve lower order Theory of Mind tasks by using different strategies. Therefore, perhaps by having the motor intentions of the confederate based on concrete tasks (e.g. hammering) they are able to understand what the confederate was planning to use the tool for and how they needed to hand the tool to facilitate the end goal. This is in line with the findings of MacKay and Shaw (2004) as individuals with ASD may perform better when the tasks are more literal. This is an important finding, as it suggests a possible intervention for individuals with ASD. Perhaps by grounding the work in stronger action-perception coupling tasks, they may be able to use motor interactions solve higher order Theory of Mind tasks.

The findings suggest that placement (comfortable or uncomfortable) of the tools did not appear to interact with the motor actions of both groups, as they appeared to give the tools to the confederate in a comfortable manner (in relation to the confederate) regardless of the initial orientation of the tool. This demonstrates that the individuals performed a task that required an initial awkward posture in order to maximize the efficiency (less tool manipulation) of the confederate, and which both the controls and individuals with ASD performed when the confederate was to use the tool for the intended purpose. Also the results that both groups placed the tools on their contralateral side, (ipsilateral side of confederate) when the confederate used the tool, demonstrates further anticipation of the motor intentions by the participants. The lack of change in behaviour (as shown by the figure 3B and 3C) suggests also that individuals with ASD perform the task in the same manner and did not modify their actions over trials. This suggests that they were able to anticipate the motor actions of the confederate without prior interactions with the confederate in this paradigm.

General Discussion

The findings of the experiments demonstrate how individuals, both control and with ASD, were able to use Theory of Mind (ToM) to facilitate the beginning state comfort of a confederate. The authors argue that the participants perceived the end goal as the action performed by the confederate, thus the individuals based their actions accordingly to maximize the beginning state comfort of the confederate (i.e. turn the tool in the proper manner, allowing the confederate to use the tool without further manipulation). This suggests that people coordinate their actions with that of another's so the goal can be achieved by the latter in a more efficient manner. This paradigm may also open other venues to study coordination between individuals in the general population.

To the best of our knowledge, to date this is one of the few pieces of empirical evidence to demonstrate how individuals coordinate their movements with another when sharing a common goal in this fashion. There is work suggesting how coordination is affected when placed beside another individual (Welsh et al., 2005, 2007). However, this previous work focused on how individuals behaved when moving to a target that was acquired previously by another individual and not how the two individuals coordinate movements to produce and end goal. The paradigm in this experiment required the participants to incur the cost associated with the task (adopt an awkward posture at the beginning or end) to minimize the cost of the confederate (have a beginning state comfort) to achieve the end goal (e.g. hammer the peg). This type of coordination is necessary for team settings and would be interesting to expand on, as it would be of theoretical interest to determine what objects the participants would not incur the cost of using an awkward posture (e.g. too cumbersome).

These findings also have implications for Autism research, as they imply that the ability to infer the motor intentions of others might be sparred in individuals with ASD. The authors suggest that the high action-perception coupling of the objects used in this study aided the individuals with ASD in determining the motor intentions of the confederates. The findings also expand the literature of tool use in individuals with ASD along with the ToM literature. It was evident that they were able to use the tools to complete the task (use the tools) and interact with others (anticipate actions). Although this appears contrary to the findings of Mostofsky et al. (2006) and Dziuk et al. (2007), there were methodological differences that may explain the different in results. That is

Mostofsky et al. (2006) and Dziuk et al. (2007) both deduced deficits in tool use by exploring a battery of test, which included some factors that may confound the findings (e.g., gesture to imitate). However, the procedure used in this experiment suggests that when they are asked to use a tool for the intended purpose, not only were they able to complete the task, but were also able to pre-plan their motor actions (used end state comfort). Since the findings are limited to end-state comfort and the procedure was not able to measure reaction times, so direct comparison to Glazebrook et al. (2009) and Rinehart et al. (2006) cannot be made. However, it is important to note that the findings of Glazebrook et al. (2009) and Larson, Bastian, Donchin, Shadmehr, and Motofsky (2008) suggest that individuals with ASD are able to complete tasks, just in a slower manner. Therefore, the general findings of this study are in accordance with the previous findings which suggest that individuals with ASD can complete tasks. The findings of ToM were also extended, as perhaps these individuals can infer motor intentions based on the goal of the task and the action possibilities of objects.

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Table 1.

Percentage (%) of Trials that Participants used Dominant Hand During Self Tasks.

Tool	**Orientation**	**Action**	**ASD**	**SD**	**Control**	**SD**
Hammer	Uncomfortable	Set	80	35	100	0
		Hammer	90	32	100	0
	Comfortable	Set	80	35	100	0
		Hammer	90	32	100	0
Calculator	Uncomfortable	Set	95	16	100	0
		Calculate	82	39	100	0
	Comfortable	Set	88	25	100	0
		Calculate	100	0	100	0
Stick	Uncomfortable	Set	80	35	100	0
		Hammer	85	31	100	0
	Comfortable	Set	78	34	100	0
		Hammer	85	34	100	0

Table 2.

Percentage (%) of Trials that Participants Placed Tools on Contralateral Side During Self Tasks.

Tool	**Orientation**	**ASD**	**SD**	**Control**	**SD**
Hammer	Uncomfortable	53	26	21	25
	Comfortable	57	26	17	22
Calculator	Uncomfortable	55	29	12	19
	Comfortable	42	31	10	20
Stick	Uncomfortable	53	27	19	23
	Comfortable	53	13	19	23

Table 3.

Percentage (%) of Trials that Participants Exhibited End-state Comfort During Self Tasks.

Tool	Orientation	Action	ASD	SD	Control	SD
Hammer	Uncomfortable	Set	90	32	100	0
		Hammer	100	0	100	0
	Comfortable	Set	90	32	100	0
		Hammer	100	0	100	0
Calculator	Uncomfortable	Set	98	5	100	0
		Calculate	53	48	63	48
	Comfortable	Set	90	32	100	0
		Calculate	100	0	100	0
Stick	Uncomfortable	Set	90	26	100	0
		Hammer	100	0	100	0
	Comfortable	Set	93	21	100	0
		Hammer	100	0	100	0

Table 4.

Percentage (%) of Trials that Participants Used Dominant Hand During Working with Other Tasks.

Interaction	Tool	Orientation	Action	ASD	SD	Control	SD
Hand	Hammer	Uncomfortable	Set	88	31	100	0
			Hammer	80	42	100	0
		Comfortable	Set	88	31	100	0
			Hammer	80	42	100	0
	Calculator	Uncomfortable	Set	100	0	100	0
			Calculate	100	0	100	0
		Comfortable	Set	100	0	100	0
			Calculate	100	0	100	0
	Stick	Uncomfortable	Set	90	32	100	0
			Hammer	90	32	90	29
		Comfortable	Set	90	32	100	0
			Hammer	90	32	100	0
Place	Hammer	Uncomfortable	Set	85	34	100	0
			Hammer	88	32	100	0
		Comfortable	Set	83	33	100	0
			Hammer	80	42	100	0
	Calculator	Uncomfortable	Set	100	0	100	0

		Calculate	100	0	88	35
	Comfortable	Set	97	11	100	0
		Calculate	98	5	88	35
Stick	Uncomfortable	Set	85	34	100	0
		Hammer	90	32	100	0
	Comfortable	Set	85	34	100	0
		Hammer	80	42	100	0

Table 5.

Percentage (%) of Trials that Participants Placed Tool on their Contralateral Side During Working with Other Tasks.

Tool	Orientation	Action	ASD	SD	Control	SD
Hammer	Uncomfortable	Set	48	25	29	31
		Hammer	87	19	98	6
	Comfortable	Set	57	29	25	36
		Hammer	92	14	98	6
Calculator	Uncomfortable	Set	47	30	23	33
		Calculate	52	44	100	0
	Comfortable	Set	57	30	27	39
		Calculate	63	44	96	12
Stick	Uncomfortable	Set	55	29	21	32
		Hammer	78	34	96	8
	Comfortable	Set	55	28	29	34
		Hammer	87	25	98	6

Table 6.

Percentage (%) of Trials that Participants Exhibited End-state Comfort During Working with Other Tasks.

Interaction	Tool	Orientation	Action	ASD	SD	Control	SD
Hand	Hammer	Uncomfortable	Set	90	32	100	0
			Hammer	90	32	100	0
		Comfortable	Set	83	36	100	0
			Hammer	73	44	98	6
	Calculator	Uncomfortable	Set	100	0	100	0
			Calculate	100	0	100	0
		Comfortable	Set	90	26	100	0
			Calculate	77	33	96	8
	Stick	Uncomfortable	Set	92	26	100	0
			Hammer	97	7	98	6
		Comfortable	Set	87	32	100	0
			Hammer	65	46	100	0
Place	Hammer	Uncomfortable	Set	90	32	100	0
			Hammer	75	41	100	0
		Comfortable	Set	90	23	98	6
			Hammer	80	42	98	6
	Calculator	Uncomfortable	Set	90	16	100	0

		Calculate	98	5	100	0
	Comfortable	Set	97	11	100	0
		Calculate	70	39	100	0
Stick	Uncomfortable	Set	97	7	100	0
		Hammer	95	11	100	0
	Comfortable	Set	98	5	100	0
		Hammer	68	48	100	0

Table 7.

Percentage (%) of Trials that Confederate Received Tool in Comfortable Manner During Working with Other Tasks.

Interaction	Tool	Orientation	Action	ASD	SD	Control	SD
Hand	Hammer	Uncomfortable	Set	88	31	100	0
			Hammer	97	7	100	0
		Comfortable	Set	27	44	63	52
			Hammer	65	46	100	0
	Calculator	Uncomfortable	Set	100	0	100	0
			Calculate	100	0	100	0
		Comfortable	Set	22	42	25	38
			Calculate	55	34	100	0
	Stick	Uncomfortable	Set	80	42	100	0
			Hammer	80	38	100	0
		Comfortable	Set	23	42	10	29
			Hammer	73	44	100	0
Place	Hammer	Uncomfortable	Set	78	42	88	35
			Hammer	87	32	100	0
		Comfortable	Set	12	31	0	0
			Hammer	48	51	100	0
	Calculator	Uncomfortable	Set	85	32	100	0

		Calculate	97	7	100	0
	Comfortable	Set	10	32	13	35
		Calculate	53	48	100	0
Stick	Uncomfortable	Set	82	38	100	0
		Hammer	67	47	100	0
	Comfortable	Set	2	5	0	0
		Hammer	68	44	100	0

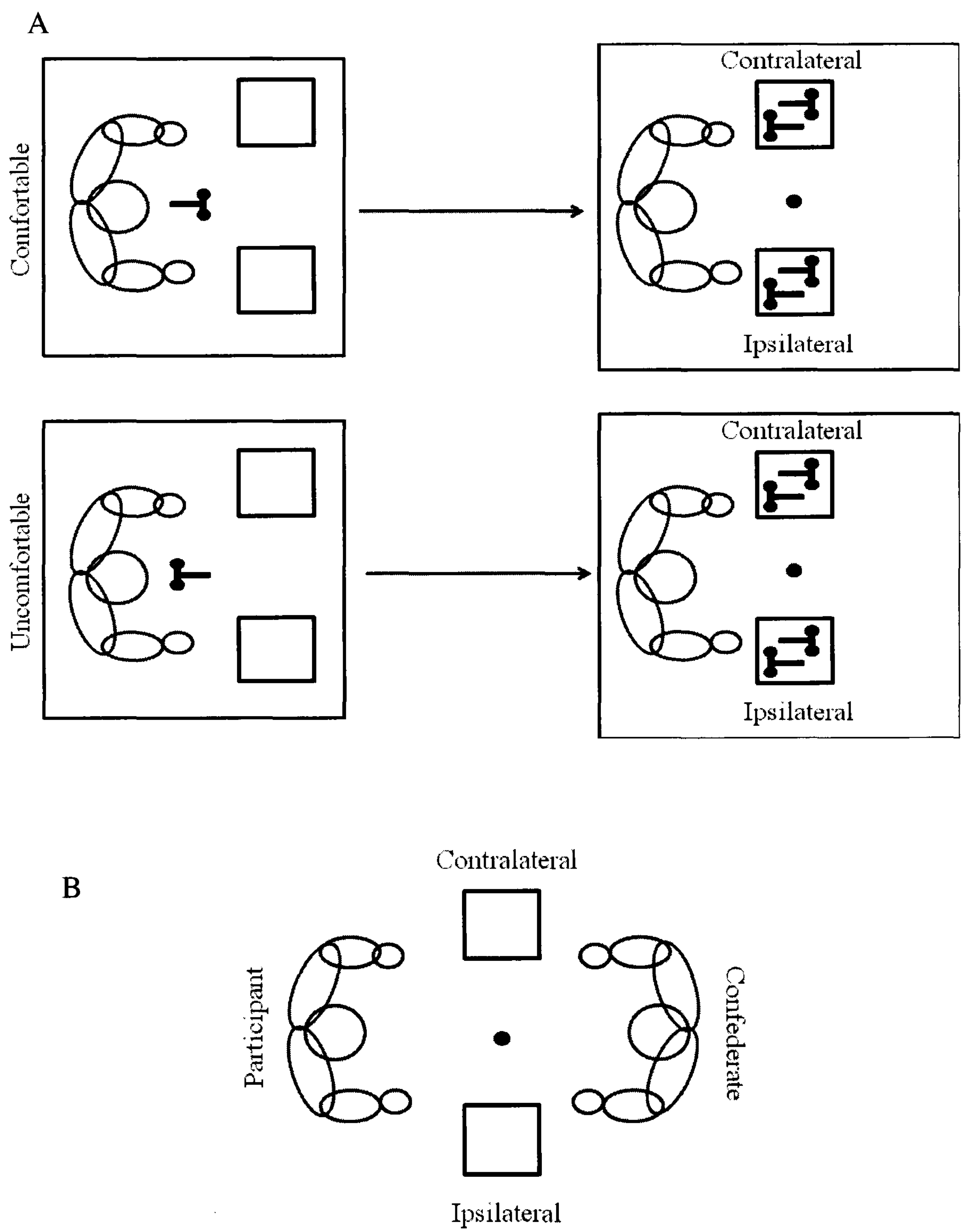
Figure Captions

Figure 1. **A** Schematic of experimental set up and all variants possible for tool placement. **B** Schematic of participant and confederate.

Figure 2. The percentage of times participants handed the tool to the confederate in a comfortable orientation in regards to the confederates.

Figure 3. **A** Data for each participant in the ASD group for all three conditions when the actor was handed the tool and used it for its intended purpose. **B** All the trials for the individuals with ASD in the hand tool and use for intended purpose condition.

Figure 4. **A** Data for ASD group for all three conditions when the actor was handed the tool but was not to use it for its intended purpose. **B** All the trials for individuals with ASD in the hand tool and not use for intended purpose condition.


A
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B
Contralateral
Participant
Confederate
Ipsilateral

Figure 1.

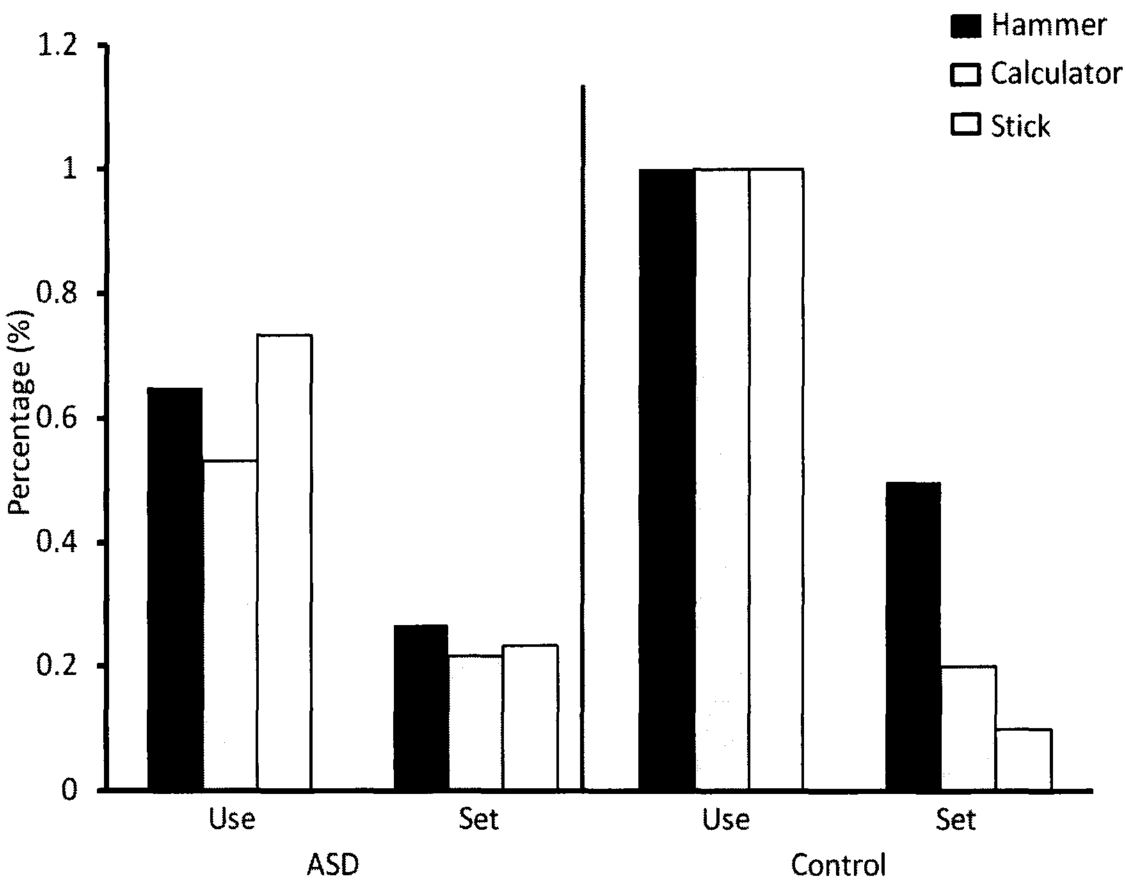
Hammer
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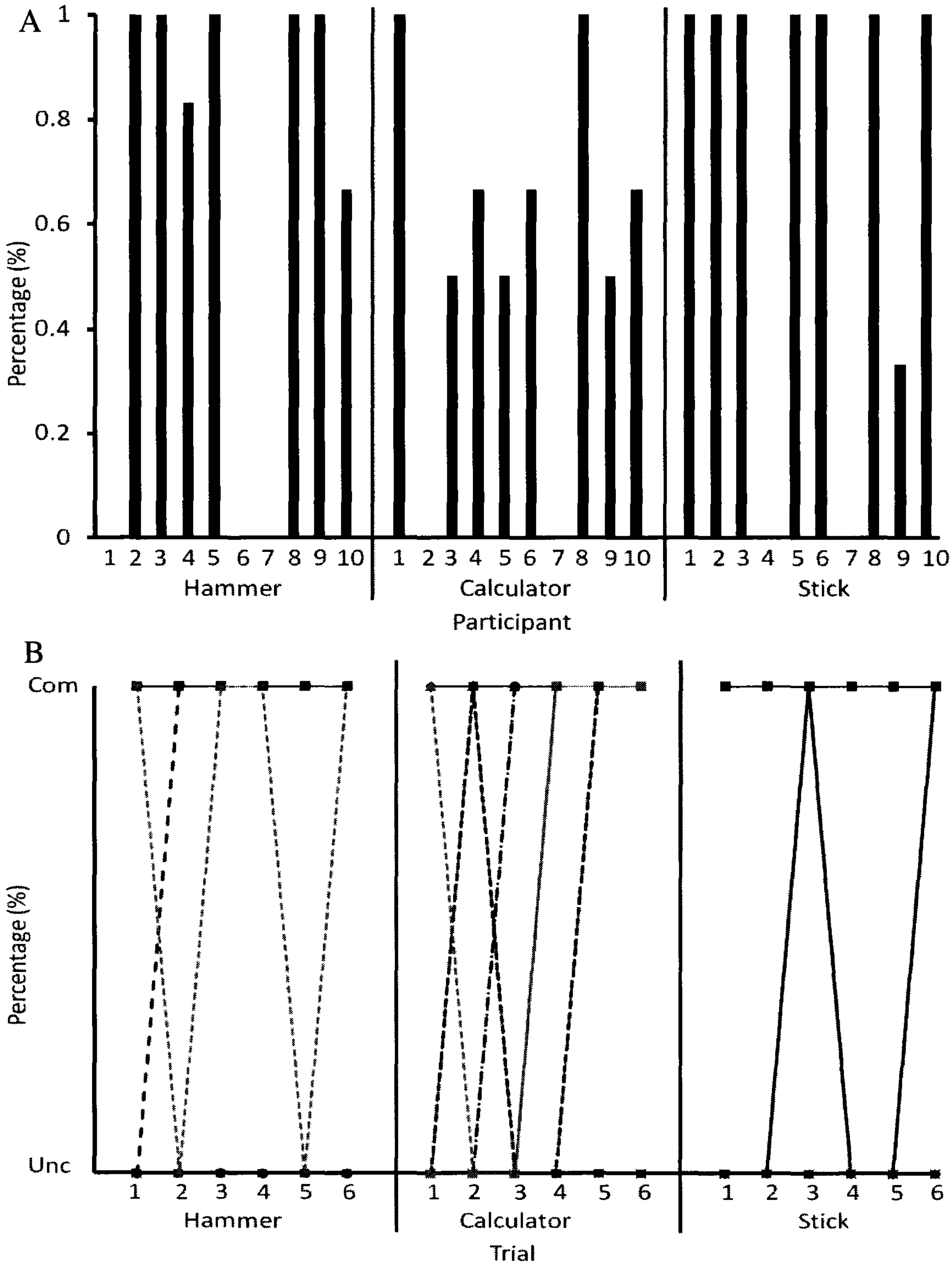
Figure 2.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Hammer
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Calculator
1 2 3 4 5 6 7 8 9 10
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1 2 3 4 5 6
Hammer
1 2 3 4 5 6
Calculator
1 2 3 4 5 6
Stick
Trial

Figure 3.

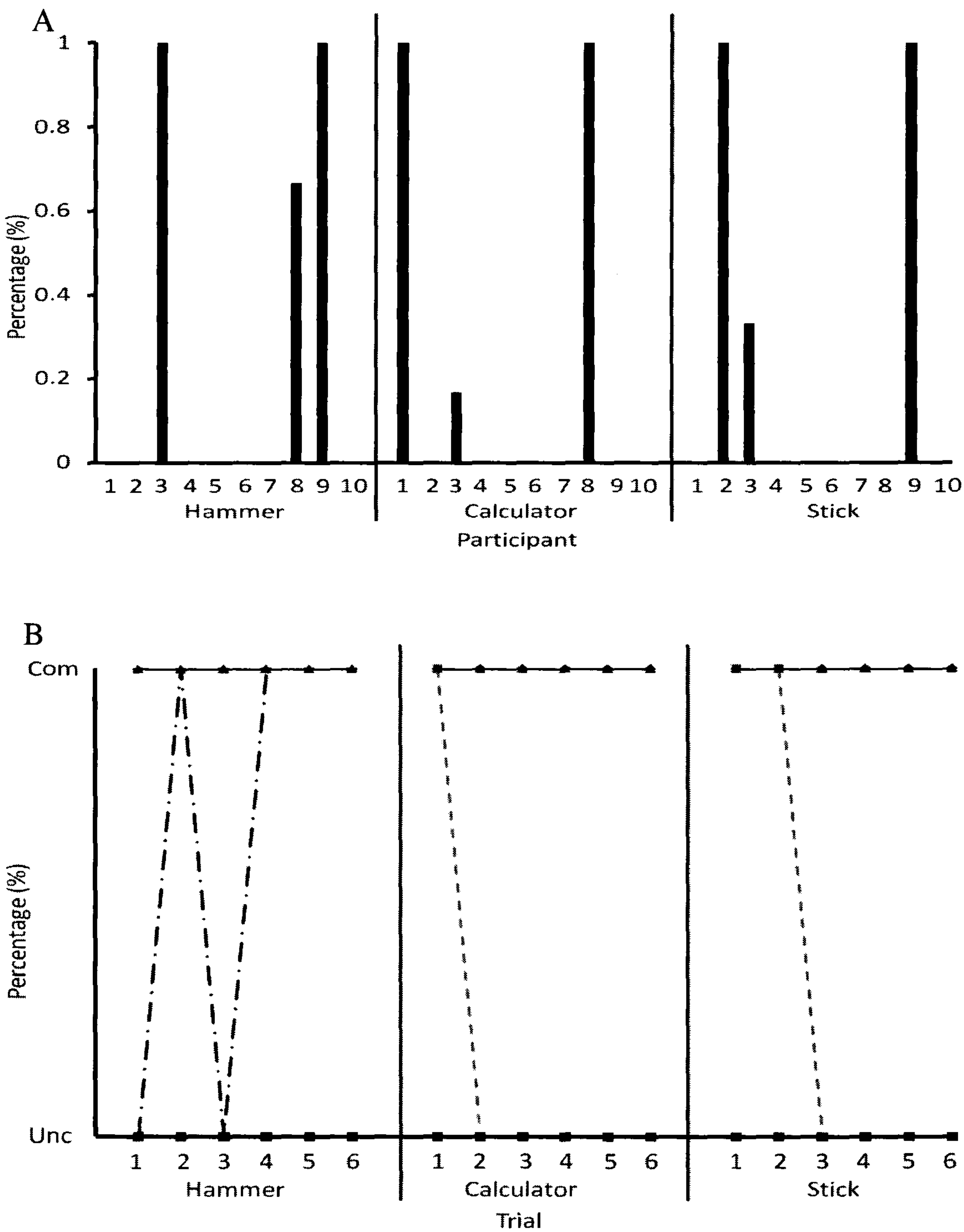
A
1
0.8
0.6
0.4
0.2
0
Percentage (%)
1 2 3 4 5 6 7 8 9 10
Hammer
1 2 3 4 5 6 7 8 9 10
Calculator
1 2 3 4 5 6 7 8 9 10
Stick
Participant
B
Com
Unc
Percentage (%)
1 2 3 4 5 6
Hammer
1 2 3 4 5 6
Calculator
1 2 3 4 5 6
Stick
Trial

Figure 4.

GENERAL DISCUSSION

This dissertation sought to expand the knowledge of motor impairments in individuals with Autism Spectrum Disorder (ASD). There are relative few findings that suggest motor impairment in this population, either in motor planning (Glazebrook et al., 2009; Hughes, 1996; Nazarali et al., 2010; Rinehart et al., 2006) or movement execution (Glazebrook et al., 2009; Mari et al., 2003) compared to the social deficits observed. Therefore, it is important to understand the extent of these impairments, as it is evident that individuals with ASD are able to complete tasks (Glazebrook et al., 2009; Larson et al., 2008) albeit differently when kinematic variables were measured (Glazebrook et al., 2009; Mari et al., 2003). This has much theoretical interest from both the ASD research and movement research, as there is a need to understand the capabilities of individuals with ASD and how to maximize the potential of their abilities.

To understand the abilities of an individual, we explored how the individuals interacted with objects and other individuals. This dissertation was aimed at studying how these interactions could be facilitated by employing objects and contexts that have a strong action-perception coupling. The reason to use these types of objects and contexts would be to take advantage of the perceived possible actions associated with them. Direct Perception Theory, and specifically affordances, would argue that a person is able to perceive the inherent 'action possibilities' of an object (Gibson, 1977). Affordances may be seen throughout the world, as riser height of stairs (Warren, 1984) for example, have often been designed to account for leg length or parameterized to body length.

However there is also an indirect perception of affordances. These may include social contexts (Schmidt, 2007) and involve a greater degree of top-down processing wherein an event is present before the association between the object and the affordance is made. An example of this concept is represented by an object that affords certain sentiments (e.g., receiving a gift). However the ability of perceiving these action possibilities are dependent on the person's capabilities, which suggests that different individuals may perceive two completely different action possibilities from the same object. Based on this notion, it was of theoretical interest to determine how individuals with ASD would perceive and use affordances from different objects and scenarios, as the capabilities of individuals with ASD may differ from those of control participants.

There is evidence to suggest that individuals with ASD have a very literal association with an object and what they perceive, as Pelicano (2007) demonstrated that individuals with ASD were more likely than controls to say that they expected pencils inside a Smarties™ tube after been shown that pencils were inside the tube. That is, after they were informed that pencils were inside, the individuals with ASD were asked "what did you think was inside before we showed you the pencils?" most of the individuals answered that they believed pencils were inside before they were shown. This suggests that they have a literal association with what is inside (pencils) and what the object is used for (in this particular case, pencil holder). This finding was also shown for reading performance as individuals with ASD had more difficulty with figurative language and less difficulties with literal meanings (MacKay & Shaw, 2004). Therefore, perhaps individuals with ASD have a very literal meaning of objects and their environment, which may be perfectly suited to perceive affordances with strong action-perception couplings. Perhaps objects that have a strong affordance (e.g., hammer) would facilitate interactions with that object and provide a great venue to facilitate motor actions for individuals with ASD.

However, the findings of this dissertation were ambiguous in this regard, as the first study did not demonstrate a hand advantage for the side the handle was oriented towards. This did not support the findings of Tucker and Ellis (1998) that proposed individuals had faster reaction times with the effector that was on the same hemispace as the handle; as this experimental procedure should afford an interaction with the effector that is on the same side as the handle. Different reasons could explain why the results differed in the first study of this dissertation and that of Tucker and Ellis (1998). First, Clark (1973) proposed that language is not fixed, and suggested that individuals should analyze stimuli to determine that the different stimuli are equal across conditions. Since the stimuli in the first study were different to those of Tucker and Ellis (1998) perhaps different responses were made and the hand advantage was not evident. Maybe stimuli are not fixed, and different objects may afford different responses. Another possible explanation is that the individuals in this experiment did not pay attention to the orientation of the handle, as it was not the immediate purpose of the protocol (e.g., press button if upside-down). Perhaps participants were more engaged on the primary task in this protocol. This latter explanation was the basis for an extension into study 2, to determine if by expanding the action component of the objects there would be an advantage for tools that afford those actions.

The second study extended the action component, via 'action words' (Holt & Beilock, 2006) and also introduced the concept of the third person. The results of the second study demonstrated that individuals with ASD were able to accurately determine the tool that was required to complete the action in the sentence. The accuracy scores did not reveal any group differences, suggesting that the individuals with ASD were as accurate as the control individuals, albeit slower in responding. This suggests that individuals were able to read the sentence and associate what tool was required to complete the action of another person (third person narrative). This finding is in accordance with the findings of Holt and Beilock (2006), who demonstrated that controls are faster to respond to an image that has a strong association with a sentence than those that do not; and with the findings of Ozonoff et al. (1991) as they suggested individuals with ASD can solve lower order ToM problems. However, these findings make it hard to discern whether the individuals with ASD were responding to the perception of the action or the person, as the individuals with ASD could simply be determining the tool required to complete the action without considering the person performing the action.

The third study aimed to answer this discrepancy by directly engaging the participants with a confederate in which by the participants coordinate their actions with the objective of the task. This introduced a new paradigm was examined by using end-state comfort. That is, could a person extend their end-state comfort to account for the beginning state comfort of another individual. The results of the third study demonstrated that both controls and individuals with ASD were able to orient that tool in a fashion which minimized the amount of manipulation the confederate required before using the tool (allowed for beginning state comfort). This suggests that when the task and the tool exhibit a strong action-perception coupling (e.g., hammer affords hammering) the individuals with ASD are able to cooperatively perform the joint action with another.

These findings expand upon the knowledge of joint action, specifically the ASD literature on joint action. It is widely regarded that individuals with ASD demonstrate difficulties in ToM (Baron-Cohen et al., 1985) and lack of social reciprocity (American Psychiatric Association, 2000); however, this experiment (study three) sought to explore the role of affordances in situations where an individual would directly interact with another person to aid the performance of a common goal. This level of interaction demonstrated that not only controls, but individuals with ASD incur the cost of the movement to aid the confederate in obtaining the goal (e.g., hammering the peg). This extends the findings of end-state comfort, as it was previously believed that individuals perform under a cost-benefit analysis when planning their movements (Rosenbaum & Jorgensen, 1992; Rosenbaum et al., 1993, 2001). In this paradigm, the participant incurred all of the cost for the benefit of the confederate, thereby suggesting that the individuals might have acted as a single identity, rather than two separate ones. This would require the participants to place themselves in the position of the other person and think about how to maximize the comfort for that individual. This was evident for both groups (controls and individuals with ASD) as they often adopted an awkward hand posture to aid the confederate.

The overall findings of this dissertation support the notion that individuals with ASD seem to have a very literal connection with their environment and others. Therefore, it would seem that objects and/or social contexts that have a strong action-perception association could be beneficial in alleviating social interactions deficits, especially ToM problems. Underconnectivity Theory would suggest that complex sensory integration might be more difficult for individuals with ASD (e.g., Dawson et al., 2002) and ToM would suggest that perceiving the intentions of other individuals may be more difficult for them as well (Baron-Cohen et al., 1985; Ozonoff et al., 1991). The role that indirect perception plays in ASD has not been well studied, but has been alluded to in some studies (MacKay & Shaw, 2004; Pelicano, 2007). Movement impairments (Glazebrook et al., 2009; Hughes, 1996; Rinehart et al., 2006) and impairments of tool use (Dzuik et al., 2007; Motofsky et al., 2006) have also been demonstrated. The general trends demonstrate that the individuals with ASD were able to accomplish the task goals, albeit using more variable kinematic movements (Glazebrook et al., 2009). The current research strengthens these arguments by suggesting that individuals with ASD may be able to complete the same tasks as the typically developed, and may interact better with tools and others when there is a strong connection between task and action.

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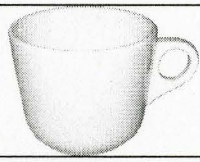
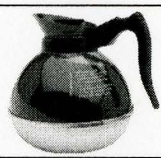
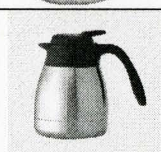
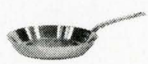
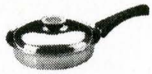
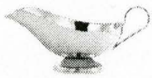
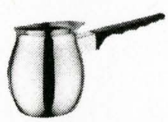
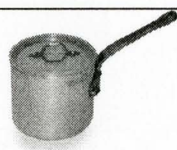
Appendix 1

Coffee Cup	
Coffee Cup2	
Coffee Cup3	
Coffee Mug	
Coffee Mug2	
Coffee Mug3	
Coffee Pot	
Coffee Pot2	
Coffee Pot3	
Frying Pan	

Frying Pan2	
Frying Pan3	
Gravy Boat	
Gravy Boat2	
Gravy Boat3	
Pitcher	
Pitcher2	
Pitcher3	
Pot	
Pot2	

Teapot	
Teapot2	
Thermos2	

Appendix 2

Sentence	More Consistent Object	Less Consistent Object	Arbitrary Object
"Sally wants the room to smell better"	Lit Candle	Unlit Candle	Nightlight (similar to air freshener)
"Sally is leaving the house and has put everything out"	Unlit Candle	Lit Candle	Nightlight (similar to air freshener)
"Anthony is thirsty and wants something to drink"	Full Glass	Empty Glass	Can of Soup
"Anthony has finished his drink"	Empty Glass	Full Glass	Can of Soup
"James is cutting the paper in half"	Open Scissors	Closed Scissors	Cable Cutters
"James is done with the crafts and is placing everything in the drawer"	Closed Scissors	Open Scissors	Cable Cutters
"Dave opened his locker to get his	Open Lock	Closed Lock	Stopwatch of similar size and style as

shorts"			lock
"Dave has finished working out and has closed his locker"	Closed Lock	Open Lock	Stopwatch of similar size and style as lock
"Stella wants to surf the net"	Open Laptop	Closed Laptop	Surf Board
"Stella is bored of surfing the net"	Closed Laptop	Open Laptop	Surf Board
"Jim is reading a story"	Open Book	Closed Book	Blank Piece of Paper
"Jim has finished reading"	Closed Book	Open Book	Blank Piece of Paper
"Tony is watching his favourite movie"	Open Case with DVD	Open Case with no DVD	Open Case with Video Game
"Tony is done watching his favourite movie and is going outside"	Open Case with no DVD	Open Case with DVD	Open Case with Video Game
"Adrienne is preparing to eat dinner"	Plate with a Slice of Pizza	Empty Plate	Home Plate
"Adrienne is done	Empty Plate	Plate with a Slice of	Home Plate

eating dinner"		Pizza	
"Jo is cutting a box open"	Box Cutter with Blade Out	Box Cutter with Retracted Blade	Kitchen Knife
"Jo has finished cutting the box open"	Box Cutter with Retracted Blade	Box Cutter with Blade Out	Kitchen Knife
"Fred wants to watch his favourite show"	TV on	TV off	Ghetto Blaster
"Fred is done watching his favourite show"	TV off	TV on	Ghetto Blaster
"Yvonne wants to go for a run outside"	Running Shoe	Dancing Shoe	Snowshoes
"Yvonne is going dancing"	Dancing Shoe	Running Shoe	Snowshoes
"Esther is getting ready to boil some water"	Pot	Pan	Cooking Sheet
"Esther is getting ready to fry some chicken"	Pan	Pot	Cooking Sheet

"Dan thinks it is too sunny"	Visor	Tuque	Sweatband
"Dan's head is cold and he wants to warm it up"	Tuque	Visor	Sweatband
"Mary wants to read her book, but she can't see like this"	Reading Glasses	Sun Glasses	Wielding Visor
"Mary is shielding her eyes from the sun"	Reading Glasses	Sun Glasses	Wielding Visor
"Johanna is being woken up in the morning"	Alarm Clock	Stop Watch	Compass
"Johanna wants to see how long Johnny can hold his breath"	Stop Watch	Alarm Clock	Compass
"Andrea is racing in the regatta"	Row Boat	Cruise Ship	Swan Paddle Boat
"Andrea is going out on the ocean"	Cruise Ship	Row Boat	Swan Paddle Boat

"Brian needs to get to an appointment a few blocks away"	Tram	Train	Tank
"Brian sees something coming down the railroad tracks"	Train	Tram	Tank
"Mel wants to take a tour of Niagara Falls from the air"	Helicopter	Plane	Air Glider
"Mel wants to take a vacation overseas"	Plane	Helicopter	Air Glider
"Mateo spilled juice on the kitchen floor and needs to wash it"	Mop	Vacuum	Garden Hose
"Mateo spilled on the carpet and needs to clean it up"	Vacuum	Mop	Garden Hose
"Stacey is going swimming and wants to see	Water Goggles	Skii Goggles	Hockey Helmet

underwater"			
"Stacey is going skiing"	Skii Goggles	Water Goggles	Hockey Helmet