Abstract: Background: Children with Autism Spectrum Disorder (ASD) have difficulty communicating with others nonverbally, via mechanisms such as hand gestures, eye contact and facial expression. Individuals with ASD also have marked deficits in planning future actions (Hughes, 1996), which might contribute to impairments in non-verbal communication. Perspective taking is typically assessed using verbal scenarios whereby the participant imagines how an actor would interact in a social situation (e.g., Sally Anne task; Baron-Cohen, Leslie, & Frith, 1985).

Method: The current project evaluated motor perspective taking in five children with ASD (8-11 years old) as they participated in a narrative intervention program over the course of about 16 weeks. The goal of the motor perspective-taking task was to facilitate the action of an experimenter either hammering with a tool or putting it away. Results: Initially, children with ASD facilitated the experimenter's action less than neurotypical control children. As the narrative intervention progressed, children with ASD exhibited increased motor facilitation that paralleled their increased use of mental state and causal language, indicating a link between verbal and motor perspective taking.

Conclusions: Motoric perspective taking provides an additional way to assess understanding and communication in children with ASD and may be a valuable tool for both early assessment and diagnosis of children with ASD.

What this paper adds?
This paper provides the first evidence in support of the association between verbal and motor perspective taking. A motor perspective taking task is introduced and tested, laying the groundwork for future research aimed at improving social communication and interaction through motor training, better and alternate methods for early detection of ASD, and potentially information for further subtyping of ASD.
January 13, 2017

Dear Research in Developmental Disabilities,

We appreciate the change to revise and resubmit our manuscript, entitled *Motor and Verbal Perspective Taking in Children with Autism Spectrum Disorder: Changes in Social Interaction with People and Tools*, for re-review as a Research Paper.

We have added some literature to the document, which bolsters our motor planning paradigm. As well, we now discuss some limitations and caveats to our findings. We hope this research will lay the groundwork for further studies on motor planning in individuals with Autism Spectrum Disorder.

Our specific responses to the editor’s and reviewer’s comments are below.

Thank you again for your consideration, and we look forward to any feedback.

Sincerely,

Breanna E. Studenka
Sandra L. Gillam
Daphne Hartzheim
Ronald B. Gillam

Editor’s comments:
* Intro: Consider additional references and stronger justifications suggested by Reviewers. Then, reflect on these in comparison to your study in the Discussion.
  - see comments to reviewers 1 and 4

* Consider Reviewer 1’s comments regarding overstating.
  - see comments to reviewer 1

* Methods: Check tables and narrative with regard to participant descriptions and address Reviewer 4’s other questions regarding participant descriptions.
  - see comments to reviewer 4

* A Materials and Setting section is needed.
  - p. 6 - Materials and Setting subheading has been added.

* Add a section for Experimental Design and describe this thoroughly.
  - p. 9 – Experimental Design subheading has been added.

* Describe the interventionist(s) and expand on the description of interobserver agreement per Reviewer 4’s suggestion. IOA needs its own section also.
We’ve added a section for IOA and reported the inter-rater reliabilities for the three rated measures, beginning-state comfort, end-state comfort, and experimenter manipulation (page 14).

* Results: Please start this section with a general statement regarding the presence or absence of a functional relation between the intervention and your target DV, supported with the graphed results.
- p. 14 – A sentence was added stating the relationship.

Within the descriptions of the results by participant, reflect on the change to trend, variability, and level of the data within and across phases. This is standard for reporting SCED results.
- We have created an additional table to report means and standard deviations for baseline and treatment phases as well as percent change from baseline to treatment for all ASD participants. Please let us know if there is a more preferred metric we can calculate.

* Disregard Reviewer 1’s comment -- Tau U is acceptable for single-case research, so thank you for including it.
– NA

* Figures 5 and 6 need some explanation (in a figure note or with arrows or otherwise). Which symbols represent PTI scores? PTI needs to be defined/spelled out in the note. Also, the data path lines should break between phases.
- p. 31 – more explanation was added to the figure captions and figures were re-plotted with breaks between phases.

* Address Reviewer 4’s other comments about the figures.
- see comments to reviewer 4

* Address miscellaneous suggestions related to grammar, spelling, and formatting.
- see comments to reviewers 1 and 4

* Discussion: See reviewer 4’s suggestions regarding reflecting on your hypothesis and reflecting on prior literature.
- see comments to reviewer 4

* Address the limitations discussed by Reviewer 1.
- see comments to reviewer 1

Reviewer #1: Review:
A. Originality/novelty/importance: This works compares perspective taking ability of neurotypical children to children with ASD as well as the relationship between verbal and motor perspective taking. "Paper provides the first evidence in support of the association between verbal and motor perspective taking."

This is an important line of study because there is a close relationship between language and motor ability (and gesture use) in children with typical development and in populations with language-impairment. However, care must be taken not to overstate results of one type of motor task (motor-social perspective taking or handling of a tool for another's use in hammering) to one clinical feature of autism spectrum disorder; specifically deficits in reciprocal social communication (i.e., as measured here in narrative productions of linguistic or verbal perspective taking). The parallels highlighted may
be related to other neurodevelopmental areas, namely individual differences in language, autism severity, motor apraxia or other weaknesses, and/or cognition.

- **We've addressed this comment in several ways. We've added some caveat of our conclusions on page 21, stating that it's possible that improvements caused by the verbal perspective taking intervention also improved things that might aid in the social-motor task, but might not be directly related to motor perspective taking. We also now discuss visual perspective taking in the introduction (pages 4-5). We also now have included a paragraph outlining limitations of the study.**

**B. No ethical issues are identified.**

**C. Text presentation**

1. Abstract: Restate implication: Motor perspective taking provides for an additional method to assess communication... (Avoid words such as alternative or better?); see notes about study limitations below
   - p.2, Changed “alternate” to “additional”

2. Introduction:
   * Please explain: page 2 ("However, perspective taking in social-motor interaction has only been explored in high-functioning adults with ASD who have more general motor and social experiences than children with ASD."). Define social-motor interaction task/more detail for reader is needed; past research and development of task? Has it been explored in the neurotypical population?
   - p.4, the motor perspective taking task has only been used in two previous studies, both with adults. The task is more thoroughly described here (middle of first paragraph). Mention is also made of the experiment that utilized this task for neutotypical adults.

   How does it relate to classic Level 1, 2 Visual Perspective Taking tasks as described in the literature? The social-motor interaction task also incorporates some level of visual perspective taking, correct?
   - p.4-5, A paragraph has been added describing how visual perspective taking may play a role in the social-motor task.

3. Materials & Methods:
   * Page 5- what does this mean- all social-motor interaction tasks were performed either on a separate day or at the end of the narrative intervention session? - may be explained on page 7?
   - p.9, We've fixed this to state: “all social-motor interaction tasks were performed once per week, following the narrative intervention session.”

   * Page 5- can leave out 1964 Helsinki declaration information; move up IRB note to beginning of procedure section
   - fixed

   * Page 5- re-words; participants came in for. . . where? Who administered trainings?
   - p.9-10, more details are added for where the trainings were administered and by whom.

   * Page 5- was verbal perspective taking (narrative training) based on past research. Description is somewhat vague- more information is needed so that the treatment may be provided in a similar way by the reader. For example, what feelings were targeted; what characters and stories were used, etc. What methods were used to practice causal language production?
   - The narrative training was quite extensive and is detailed in another published manuscript. Rather than go into extant details of the narrative intervention in this paper, we’ve referenced the published work. P. 10
3. Results:

* Non-parametric statistics would be more appropriate to compare groups with small n.
Variability/outliers are apparent in this work.

*Editor said to disregard this comment. Tau-U is fine.

4. Discussion:

* Must discuss limitations- 4 major limitations- ASD participants were not tested to rule out motor apraxia prior to the testing and treatment. It is impossible to state if results of the motor task were related to apractic-like motor hand differences.

*p21-22, this is mentioned in the new limitations section.

* Second major limitation is that the examiner modeled the orientation needed to complete the hammer task in practice sessions (16 sessions). It is unclear if participants with ASD benefited from the manipulation, but it stands to reason that over several practice attempts that participants may adjust their hands because the examiner had re-adjusted previously. Note that the investigator deliberately turned the object around in the correct manner (page 7).

*The experimenter actually did not model anything, only held out his or her hand and took the object once the participant handed it over. There were no practice sessions. The only “cue” an participant would have had as to whether they “helped” or not was that the experimenter had to turn the object around if the wrong side was handed over (e.g., the hammer head was placed into his/her hand rather than the handle). In this case, the action was very deliberate, but not emphasized. The experimenter placed the object into his own left hand and then back into his right hand in the correct orientation and them proceeded to hammer. We’ve tried to make this explanation more clear, p. 12.

* Third limitation- participants had been given the ADOS yet; no autism severity scores were reported. Differences in linguistic and motor perspective taking may also be related to autism severity.

*Fourth limitation- small n and much variability in participants in terms of language and cognitive abilities.

*Confusing discussion- it may be that the treatment improved the targeted linguistic ability for some participants; yet it is difficult to state with certainty that social- motor perspective taking paralleled linguistic perspective taking over consecutive sessions (i.e., lack of generalization of skill over several sessions; or chance, etc.). More information is needed on how this was determined. Cut-off scores? Visual inspection?

*p. 19, more detail is added here as to how the conclusion was made that social-motor perspective taking paralleled linguistic perspective taking.

* Page 16- last paragraph; replace "better" with additional non-verbal means of measuring perspective in individuals. Do not over-state the results because it may be that improvements or lack of
improvements were related to individual differences in terms of motor, social, communication, and cognitive ability—absent measures of motor and autism severity.

-p. 23, this has been fixed. As well, we added some caveat to our findings on page 21 at the bottom of the 2nd paragraph.

* More explanation about different learners—low language and/or low cognitive abilities will impact results; autism severity will likely impact results; motor apraxia

- We didn’t specifically test language or cognitive abilities and with our low sample size, we can’t really make any definite conclusions about cognitive ability and perspective taking. We do, however, mention that the two subjects who performed most poorly on both the verbal and motor task also had the lowest nonverbal reasoning ability (UNT) and CELF-4 scores (p.19).

Reviewer #4: Summary: This study compared motor-perspective taking ability of children with ASD and a neurotypical control group. Children with ASD participated in a narrative intervention, while simultaneously being assessed on a motor-perspective taking task. Neurotypical children were only assessed on the motor-perspective task. Children with ASD were not as proficient at their neurotypical peers on the motor-perspective tasking task; however, as the intervention progressed, the performance of children with ASD improved.

General comments: Overall, the study was well designed and the paper is well written. Given the dearth of literature on the topic, and the need for further investigation in the field, the manuscript could be acceptable for publication, but would benefit from specific changes. I therefore recommend revisions, based on the following:

Minor points:
- Page 1: "such deficits have been associated with insufficient understanding of the perspective of another individual" → Please provide a reference for this statement.
- p.3, A reference has been added here, and the sentence re-worded.

- Page 8: "A minimum criteria for the PTI was set at 6," → "6" does not need to be underlined.
- We have fixed this.

- Page 1: you use "neuro-typical" here, but in other places "neurotypical" please keep consistent.
- This has been fixed throughout the manuscript.

- Page 2: "typical…and atypical" → are you referring to typically development?
- this has been re-worded to be more clear.

- Page 3: "The first person" → participant?
- “person” has been changed to “participant”

Major points:
Introduction:
- Page 2: "However, perspective taking in social-motor interaction has only been explored in high functioning adults with ASD who have more general motor and social experience than children with ASD" → A recent paper (Scharoun, S. M., & Bryden, P. J. (2016). Anticipatory planning in children with Autism Spectrum Disorder: An assessment of independent and joint action tasks. Frontiers in Integrative Neuroscience, 10.), similar to Gonzalez and colleagues (2013), assessed beginning-state comfort in children with ASD.
- p. 4, We have added mention of this paper.
- Page 2: "Because of the potential impact of early assessment and detection..." → I agree with this statement; however, more evidence is required to justify this, and the purpose of your study. Although there is discussion of impairments in social communication, there is little discussion regarding other key diagnostic criteria; in particular, the notion that motor impairments are considered cardinal features of ASD but are not included in diagnostic criteria should be discussed.

-p. 5, further discussion of this has been added
- In your discussion (page 14), you highlight the end-state comfort literature as a means of explaining results, referencing Hughes (1996), and Simermeyer and Ketcham (2015) who reported less end-state comfort in children with ASD; however, others (e.g., Hamilton, Brindley & Frith, 2007; van Swieten et al., 2010) have reported no difference in end-state comfort. Your introduction would benefit from discussion of this literature.

-p.6 paragraph 2, These studies are now outlined and discussed.

- Page 3: "We hypothesized that children with ASD would exhibit less perspective taking during social-motor interaction than neurotypical children." → The assessment of end- and beginning state comfort in neurotypical children (see Wunsch, Henning, Aschersleben & Weigelt, 2013 for a review) should be briefly discussed in the introduction as a basis for your hypothesis.

-p.5, This reference has been added and briefly discussed.

Methods
- Participants: The abstract states that children were 7-9 years old; however in Table 1, participants’ ages range from 8 years, 4 months to 10 years 9 months. Please confirm.

-the table is correct, the abstract has been modified.

- Participants (p. 3): "Five age and gender matched control children were recruited..." → Looking at Table 1, although children are close in age, I would be cautious when indicating they are age matched. For example, Participant 4 is 8 years, 4 months and the matched control is 7 years, 11 months.

-p.7, this has now been changed to state the control participants were verbally matched and age matched to within one year of each child with ASD.

- Participants (p. 3): What do you mean by an "educational diagnosis of autism?"

-The children were diagnosed as having Autism by educators or special educators. We’ve specified this on page 7.

- Participants (p. 3): "Five age and gender matched control children were recruited" → by what means were these children classified as "neurotypical?" Please specify in the methods section.

-We’ve now included a description of the inclusion criteria for the neurotypical children, “These children showed no educational, social or physical disabilities”

- Please provide detail about the experimenter who completed the motor perspective taking task with participants. On Page 7, the experimenter is referred to as "he or she." Was the experimenter the same throughout the duration of the study, or were different experimenters used? How familiar were children with ASD with the experimenter? These factors may have influenced the manner in which children performed (i.e., if children were familiar with the researcher they may have performed differently if they were not familiar); therefore more detail is needed.

-p.11, details are now provided. “The experimenter was either the main author or one of her students. Each child became familiar with the student who tested him or her, and, additionally, the main author was present for every testing session.”
Page 7: "Once the object was placed into the experimenter's hand...the researcher deliberately turned the object around by placing it first into his/her left hand, and then back into his/her right hand in the correct orientation for hammering. The experimenter then brought the hands back to rest in his/her lap before the beginning the next trial" → Was the experimenter right or left handed? Did the experimenter grasp the object with the hand the participant offered the object to, or act in the same manner throughout the study?

-p.11-12, more details are added here. All experimenters were right handed. The right hand was held out (see Figure 1) “with the V between the thumb and fingers toward the participant” between the toolbox and pegs, so the participant always handed the object to this hand. This was performed the same every trial. The experimenter was even trained not to “reach” for the object, but to wait until the child put this object in his or her hand.

Page 8: "For each participant, handedness was determined by the number of trials, over the entire experience, one hand was used over another hand" → Table 1 does not indicate the hand preference of each participant. Was the hand preference of children with ASD / neurotypical control the same? Did you compare the number of trials performed with the right/left hand between the groups? Was a standard assessment of hand preference/performance used for confirmation?

-p.5, and p. 13. All participants were self/parent reported right handers. However, some chose to grasp the object predominantly with the left hand, so we’ve changed the wording to indicate the hand preferred for the task.

Page 9: "Manipulation was noted any time a participant's beginning state comfort differed from his/her end-state comfort" → Please provide a definition of beginning and end state comfort.

-p.5-6. These concepts are now better defined and described along with additional literature on end-state comfort.

Page 9: "Two experimenters scored each video independently..." → Were the coders blind to the purpose of the experiment?

-No, they were not. Mention of this has been added to the end of page 14.

Results
- Table 1: Matched Control - I believe this reports age; however, please include (years; months) if the same as your Age column.

-This has been added.

- Figures 5 & 6: Your caption describes what the colors of the circles indicate, but what do the triangles indicate?

-Triangles were the PTI scores, this is now mentioned in the figure caption.

- Figures 8, 9, 10: Do error bars represent standard error or standard deviation?

-The error bars indicate the standard error. This is now mentioned in the figure captions.

- Please note significant differences with * in your figures.

-These have been added.

- Page 12: F statements for ANOVAs require two degrees of freedom numbers; however, only one is currently reported.

-This has been fixed.

Discussion
- Page 13: Do findings support or refute your hypothesis? Please remind the reader of what you had hypothesized originally.
- p.19, A re-statement of the main hypotheses has been added to the beginning of the discussion.

- Page 14: "...two children with ASD who never reached 100% facilitation behaviour were the two subjects who had the lowest nonverbal reasoning ability (UNIT) and CELF-4 scores." → Did you run correlations to see if there were any relationships here?
- No correlations were run due to our low sample number (n=5).

- Page 14: "In tasks that require the grasp and manipulation of an object, children and adults with ASD exhibit less end-state comfort than controls" (Hughes, 1996; Simermeyer & Ketcham, 2015) → Others (e.g., Hamilton et al., 2007; van Swieten et al., 2010) have reported no difference in end-state comfort.
- p.6, These studies are now mentioned and discussed in relation to the social-motor interaction task.

- Page 14: "End-state comfort refers to ..." → This definition, and one of beginning state comfort should be earlier - definitely in methods, but also highlighted in introduction
- This has now been defined in the introduction as well as in the methods (p.13).

References
- Gonzalez et al. 2013a/b are the same reference. In text you have Gonzalez et al., 2015 cited. Did you mean to include the following paper (Gonzalez, D. A., Glazebrook, C. M., & Lyons, J. L. (2015). The use of action phrases in individuals with Autism Spectrum Disorder. Neuropsychologia, 77, 339-345.)?
- This has been fixed.
**Detailed Response to Reviewers**

Editor's comments:
* Intro: Consider additional references and stronger justifications suggested by Reviewers. Then, reflect on these in comparison to your study in the Discussion.
  - see comments to reviewers 1 and 4

* Consider Reviewer 1's comments regarding overstating.
  - see comments to reviewer 1

* Methods: Check tables and narrative with regard to participant descriptions and address Reviewer 4's other questions regarding participant descriptions.
  - see comments to reviewer 4

* A Materials and Setting section is needed.
  - p. 6 - Materials and Setting subheading has been added.

* Add a section for Experimental Design and describe this thoroughly.
  - p. 9 – Experimental Design subheading has been added.

* Describe the interventionist(s) and expand on the description of interobserver agreement per Reviewer 4's suggestion. IOA needs its own section also.
  - see comments to reviewer 4 – We've added a section for IOA and reported the inter-rater reliabilities for the three rated measures, beginning-state comfort, end-state comfort, and experimenter manipulation (page 14).

* Results: Please start this section with a general statement regarding the presence or absence of a functional relation between the intervention and your target DV, supported with the graphed results.
  - p. 14 – A sentence was added stating the relationship.

Within the descriptions of the results by participant, reflect on the change to trend, variability, and level of the data within and across phases. This is standard for reporting SCED results.
- We have created an additional table to report means and standard deviations for baseline and treatment phases as well as percent change from baseline to treatment for all ASD participants. Please let us know if there is a more prefered metric we can calculate.

* Disregard Reviewer 1's comment -- Tau U is acceptable for single-case research, so thank you for including it.
  – NA

* Figures 5 and 6 need some explanation (in a figure note or with arrows or otherwise). Which symbols represent PTI scores? PTI needs to be defined/spelled out in the note. Also, the data path lines should break between phases.
  - p. 31 – more explanation was added to the figure captions and figures were re-plotted with breaks between phases.

* Address Reviewer 4's other comments about the figures.
  - see comments to reviewer 4

* Address miscellaneous suggestions related to grammar, spelling, and formatting.
  - see comments to reviewers 1 and 4
* Discussion: See reviewer 4’s suggestions regarding reflecting on your hypothesis and reflecting on prior literature.
- see comments to reviewer 4

* Address the limitations discussed by Reviewer 1.
- see comments to reviewer 1

Reviewer #1: Review:
A. Originality/novelty/importance: This works compares perspective taking ability of neurotypical children to children with ASD as well as the relationship between verbal and motor perspective taking. "Paper provides the first evidence in support of the association between verbal and motor perspective taking."

This is an important line of study because there is a close relationship between language and motor ability (and gesture use) in children with typical development and in populations with language-impairment. However, care must be taken not to overstate results of one type of motor task (motor-social perspective taking or handling of a tool for another's use in hammering) to one clinical feature of autism spectrum disorder; specifically deficits in reciprocal social communication (i.e., as measured here in narrative productions of linguistic or verbal perspective taking). The parallels highlighted may be related to other neurodevelopmental areas, namely individual differences in language, autism severity, motor apraxia or other weaknesses, and/or cognition.

- We’ve addressed this comment in several ways. We’ve added some caveat of our conclusions on page 21, stating that it’s possible that improvements caused by the verbal perspective taking intervention also improved things that might aid in the social-motor task, but might not be directly related to motor perspective taking. We also now discuss visual perspective taking in the introduction (pages 4-5). We also now have included a paragraph outlining limitations of the study.

B. No ethical issues are identified.
C. Text presentation
   1. Abstract: Restate implication: Motor perspective taking provides for an additional method to assess communication... (Avoid words such as alternative or better?); see notes about study limitations below
   -p.2, Changed “alternate” to “additional”

   2. Introduction:

   * Please explain: page 2 ("However, perspective taking in social-motor interaction has only been explored in high-functioning adults with ASD who have more general motor and social experiences than children with ASD."). Define social-motor interaction task/more detail for reader is needed; past research and development of task? Has it been explored in the neurotypical population?
   -p.4, the motor perspective taking task has only been used in two previous studies, both with adults. The task is more thoroughly described here (middle of first paragraph). Mention is also made of the experiment that utilized this task for neototyipcal adults.

   How does it relate to classic Level 1, 2 Visual Perspective Taking tasks as described in the literature? The social-motor interaction task also incorporates some level of visual perspective taking, correct?
   -p.4-5, A paragraph has been added describing how visual perspective taking may play a role in the social-motor task.
3. Materials & Methods:
* Page 5- what does this mean- all social-motor interaction tasks were performed either on a separate day or at the end of the narrative intervention session? - may be explained on page 7? -p.9, We’ve fixed this to state: “all social-motor interaction tasks were performed once per week, following the narrative intervention session.”

* Page 5- can leave out 1964 Helsinki declaration information; move up IRB note to beginning of procedure section
- fixed

* Page 5- re-words; participants came in for. . . where? Who administered trainings?
- p.9-10, more details are added for where the trainings were administered and by whom.

* Page 5- was verbal perspective taking (narrative training) based on past research. Description is somewhat vague- more information is needed so that the treatment may be provided in a similar way by the reader. For example, what feelings were targeted; what characters and stories were used, etc. What methods were used to practice causal language production?
- The narrative training was quite extensive and is detailed in another published manuscript. Rather than go into extant details of the narrative intervention in this paper, we’ve referenced the published work. P. 10


3. Results:
* Non-parametric statistics would be more appropriate to compare groups with small n Variability/outliers are apparent in this work.
-Editor said to disregard this comment. Tau-U is fine.

4. Discussion:
* Must discuss limitations- 4 major limitations- ASD participants were not tested to rule out motor apraxia prior to the testing and treatment. It is impossible to state if results of the motor task were related to apractic-like motor hand differences
- p21-22, this is mentioned in the new limitations section

* Second major limitation is that the examiner modeled the orientation needed to complete the hammer task in practice sessions (16 sessions). It is unclear if participants with ASD benefited from the manipulation, but it stands to reason that over several practice attempts that participants may adjust their hands because the examiner had re-adjusted previously. Note that the investigator deliberately turned the object around in the correct manner (page 7).
- The experimenter actually did not model anything, only held out his or her hand and took the object once the participant handed it over. There were no practice sessions. The only “cue” an participant would have had as to whether they “helped” or not was that the experimenter had to turn the object around if the wrong side was handed over (e.g., the hammer head was placed into his/her hand rather than the handle). In this case, the action was very deliberate, but not emphasized. The experimenter placed the object into his own left hand and then back into his right hand in the correct orientation and then proceeded to hammer. We’ve tried to make this explanation more clear, p. 12.
Third limitation - participants had been given the ADOS yet; no autism severity scores were reported. Differences in linguistic and motor perspective taking may also be related to autism severity.

Fourth limitation - small n and much variability in participants in terms of language and cognitive abilities.

Confusing discussion - it may be that the treatment improved the targeted linguistic ability for some participants; yet it is difficult to state with certainty that social-motor perspective taking paralleled linguistic perspective taking over consecutive sessions (i.e., lack of generalization of skill over several sessions; or chance, etc.). More information is needed on how this was determined. Cut-off scores? Visual inspection?

Page 16 - last paragraph; replace "better" with additional non-verbal means of measuring perspective in individuals. Do not over-state the results because it maybe that improvements or lack of improvements were related to individual differences in terms of motor, social, communication, and cognitive ability - absent measures of motor and autism severity.

More explanation about different learners - low language and/or low cognitive abilities will impact results; autism severity will likely impact results; motor apraxia.

We didn't specifically test language or cognitive abilities and with our low sample size, we can't really make any definite conclusions about cognitive ability and perspective taking. We do, however, mention that the two subjects who performed most poorly on both the verbal and motor task also had the lowest nonverbal reasoning ability (UNT) and CELF-4 scores (p.19).

Reviewer #4: Summary: This study compared motor-perspective taking ability of children with ASD and a neurotypical control group. Children with ASD participated in a narrative intervention, while simultaneously being assessed on a motor-perspective taking task. Neurotypical children were only assessed on the motor-perspective taking task. Children with ASD were not as proficient at their neurotypical peers on the motor-perspective tasking task; however, as the intervention progressed, the performance of children with ASD improved.

General comments: Overall, the study was well designed and the paper is well written. Given the dearth of literature on the topic, and the need for further investigation in the field, the manuscript could be acceptable for publication, but would benefit from specific changes. I therefore recommend revisions, based on the following:

Minor points:

Page 1: "such deficits have been associated with insufficient understanding of the perspective of another individual" → Please provide a reference for this statement.

Page 3, A reference has been added here, and the sentence re-worded.

Page 8: "A minimum criteria for the PTI was set at 6," → "6" does not need to be underlined.
- We have fixed this.

- Page 1: you use "neuro-typical" here, but in other places "neurotypical" please keep consistent.  
  This has been fixed throughout the manuscript.

- Page 2: "typical…and atypical" → here are you referring to typically development?  
  This has been re-worded to be more clear.

- Page 3: "The first person" → participant?  
  "person" has been changed to "participant"

Major points:
Introduction:
- Page 2: "However, perspective taking in social-motor interaction has only been explored in high  
functioning adults with ASD who have more general motor and social experience than children with  
ASD" → A recent paper (Scharoun, S. M., & Bryden, P. J. (2016). Anticipatory planning in children with  
Autism Spectrum Disorder: An assessment of independent and joint action tasks. Frontiers in  
Integrative Neuroscience, 10.), similar to Gonzalez and colleagues (2013), assessed beginning-state  
comfort in children with ASD.  
-p. 4, We have added mention of this paper.

- Page 2: "Because of the potential impact of early assessment and detection…" → I agree with this  
statement; however, more evidence is required to justify this, and the purpose of your study. Although  
there is discussion of impairments in social communication, there is little discussion regarding other key  
diagnostic criteria; in particular, the notion that motor impairments are considered cardinal features of  
ASD but are not included in diagnostic criteria should be discussed.

-p. 5, further discussion of this has been added
- In your discussion (page 14), you highlight the end-state comfort literature as a means of explaining  
results, referencing Hughes (1996), and Simmermeyer and Ketcham (2015) who reported less end-state  
comfort in children with ASD; however, others (e.g., Hamilton, Brindley & Frith, 2007; van Swieten et  
al., 2010) have reported no difference in end-state comfort. Your introduction would benefit from  
discussion of this literature.
-p.6 paragraph 2, These studies are now outlined and discussed.

- Page 3: "We hypothesized that children with ASD would exhibit less perspective taking during social-  
motor interaction than neurotypical children." → The assessment of end- and beginning state comfort in  
neurotypical children (see Wunsch, Henning, Aschersleben & Weigelt, 2013 for a review) should be  
briefly discussed in the introduction as a basis for your hypothesis.
-p.5, This reference has been added and briefly discussed.

Methods
- Participants: The abstract states that children were 7-9 years old; however in Table 1, participants’  
ages range from 8 years, 4 months to 10 years 9 months. Please confirm.  
-the table is correct, the abstract has been modified.

- Participants (p. 3): "Five age and gender matched control children were recruited…” → Looking at  
Table 1, although children are close in age, I would be cautious when indicating they are age matched.  
For example, Participant 4 is 8 years, 4 months and the matched control is 7 years, 11 months.  
-p.7, this has now been changed to state the control participants were verbally matched and age  
matched to within one year of each child with ASD.
Participants (p. 3): What do you mean by an "educational diagnosis of autism?"

The children were diagnosed as having Autism by educators or special educators. We've specified this on page 7.

Participants (p. 3): "Five age and gender matched control children were recruited" → by what means were these children classified as "neurotypical?" Please specify in the methods section.

We've now included a description of the inclusion criteria for the neurotypical children, “These children showed no educational, social or physical disabilities”

Please provide detail about the experimenter who completed the motor perspective taking task with participants. On Page 7, the experimenter is referred to as "he or she." Was the experimenter the same throughout the duration of the study, or were different experimenters used? How familiar were children with ASD with the experimenter? These factors may have influenced the manner in which children performed (i.e., if children were familiar with the researcher they may have performed differently if they were not familiar); therefore more detail is needed.

-p.11, details are now provided. “The experimenter was either the main author or one of her students. Each child became familiar with the student who tested him or her, and, additionally, the main author was present for every testing session.”

Page 7: "Once the object was placed into the experimenter's hand...the researcher deliberately turned the object around by placing it first into his/her left hand, and then back into his/her right hand in the correct orientation for hammering. The experimenter then brought the hands back to rest in his/her lap before the beginning the next trial" → Was the experimenter right or left handed? Did the experimenter grasp the object with the hand the participant offered the object to, or act in the same manner throughout the study?

-p.11-12, more details are added here. All experimenters were right handed. The right hand was held out (see Figure 1) “with the V between the thumb and fingers toward the participant” between the toolbox and pegs, so the participant always handed the object to this hand. This was performed the same every trial. The experimenter was even trained not to “reach” for the object, but to wait until the child put this object in his or her hand.

-Page 8: "For each participant, handedness was determined by the number of trials, over the entire experience, one hand was used over another hand" → Table 1 does not indicate the hand preference of each participant. Was the hand preference of children with ASD / neurotypical control the same? Did you compare the number of trials performed with the right/left hand between the groups? Was a standard assessment of hand preference/performance used for confirmation?

-p.5, and p. 13. All participants were self/parent reported right handers. However, some chose to grasp the object predominantly with the left hand, so we’ve changed the wording to indicate the hand preferred for the task.

- Page 9: " Manipulation was noted any time a participant's beginning state comfort differed from his/her end-state comfort" → Please provide a definition of beginning and end state comfort.

-p.5-6. These concepts are now better defined and described along with additional literature on end-state comfort.

- Page 9: "Two experimenters scored each video independently..." → Were the coders blind to the purpose of the experiment?

- No, they were not. Mention of this has been added to the end of page 14.
- Table 1: Matched Control - I believe this reports age; however, please include (years; months) if the same as your Age column.
   -This has been added.

- Figures 5 & 6: Your caption describes what the colors of the circles indicate, but what do the triangles indicate?
   -Triangles were the PTI scores, this is now mentioned in the figure caption.

- Figures 8, 9, 10: Do error bars represent standard error or standard deviation?
   -The error bars indicate the standard error. This is now mentioned in the figure captions.

- Please note significant differences with * in your figures.
   -These have been added.

- Page 12: F statements for ANOVAs require two degrees of freedom numbers; however, only one is currently reported.
   -This has been fixed.

Discussion
- Page 13: Do findings support or refute your hypothesis? Please remind the reader of what you had hypothesized originally.
   -p.19, A re-statement of the main hypotheses has been added to the beginning of the discussion.

- Page 14: "...two children with ASD who never reached 100% facilitation behaviour were the two subjects who had the lowest nonverbal reasoning ability (UNIT) and CELF-4 scores." → Did you run correlations to see if there were any relationships here?
   -No correlations were run due to our low sample number (n=5).

- Page 14: "In tasks that require the grasp and manipulation of an object, children and adults with ASD exhibit less end-state comfort than controls" (Hughes, 1996; Simermeyer & Ketcham, 2015) → Others (e.g., Hamilton et al., 2007; van Swieten et al., 2010) have reported no difference in end-state comfort.
   -p.6, These studies are now mentioned and discussed in relation to the social-motor interaction task.

- Page 14: "End-state comfort refers to ..." → This definition, and one of beginning state comfort should be earlier - definitely in methods, but also highlighted in introduction
   -This has now been defined in the introduction as well as in the methods (p.13).

References
- Gonzalez et al. 2013a/b are the same reference. In text you have Gonzalez et al., 2015 cited. Did you mean to include the following paper (Gonzalez, D. A., Glazebrook, C. M., & Lyons, J. L. (2015). The use of action phrases in individuals with Autism Spectrum Disorder. Neuropsychologia, 77, 339-345.)?
   -This has been fixed.
Graphical Abstract

- Verbal perspective taking
- Motor perspective taking
- Proficiency of social communication and interaction
- Ratio of helping during the social-motor interaction task
- Linguistic markers of verbal planning (PTI)
Highlights

- Children with ASD facilitate the actions of others less than neurotypical children.
- Narrative language improved over a 16-week intervention in individuals with ASD.
- Facilitation of others’ actions improved along with narrative language skills.
Abstract

**Background:** Children with Autism Spectrum Disorder (ASD) have difficulty communicating with others nonverbally, via mechanisms such as hand gestures, eye contact and facial expression. Individuals with ASD also have marked deficits in planning future actions (Hughes, 1996), which might contribute to impairments in non-verbal communication. Perspective taking is typically assessed using verbal scenarios whereby the participant imagines how an actor would interact in a social situation (e.g., Sally Anne task; Baron-Cohen, Leslie, & Frith, 1985). **Method:** The current project evaluated motor perspective taking in five children with ASD (8-11 years old) as they participated in a narrative intervention program over the course of about 16 weeks. The goal of the motor perspective-taking task was to facilitate the action of an experimenter either hammering with a tool or putting it away. **Results:** Initially, children with ASD facilitated the experimenter’s action less than neurotypical control children. As the narrative intervention progressed, children with ASD exhibited increased motor facilitation that paralleled their increased use of mental state and causal language, indicating a link between verbal and motor perspective taking. **Conclusions:** Motoric perspective taking provides an additional way to assess understanding and communication in children with ASD and may be a valuable tool for both early assessment and diagnosis of children with ASD.

Keywords: ASD, end-state comfort, motor planning, perspective taking, narrative intervention, verbal perspective

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized, in part, by impairment in social communication (5th ed; DSM-5). Social deficits can include reduced response to social overtures of others or abnormal eye contact and/or gestures (Capps, Losh, & Thurber, 2000; Eigsti, de Marchena, Schuh, & Kelley, 2011). For example, a child with ASD may have difficulty interpreting the raising of an eyebrow to indicate surprise or the shrugging of shoulders to indicate confusion. Such deficits have been associated with impaired social communication (e.g., Beall, Moody, McIntosh, Hepburn, & Reed, 2008).

Perspective taking is typically assessed by asking questions and recording a participant’s verbal responses. In one commonly used measure, a participant watches a video of two people interacting and then describes the emotions each person may have felt during the interaction (Gehlbach, 2004). In another commonly used measure, which does not require a verbal response but does require understanding the verbal instructions of the experimenter as well as the visual perspective of the person looking at the object, a child is asked to point out which object another person is looking at (Baron-Cohen, 1989).

If individuals with ASD have trouble with verbal comprehension or communication, perspective taking could be assumed to be insufficient when, in reality, it is not. Reduced use and understanding of mental state and causal language (e.g., she thought she was in trouble because her mom looked mad) has been associated with difficulties in perspective taking (García-Pérez, Hobson, & Lee, 2008). However, a failure to use phrases such as “she thought” or “he decided to” to mark perspective may actually be related to linguistic limitations rather than deficits in the ability to take another’s perspective. Evidence for this phenomenon has come from studies of neurotypical infants in which perspective taking was measured using eye tracking rather than verbal responses. Findings revealed that young children’s eye gaze patterns demonstrated knowledge of perspective taking long before they were able to do so verbally (Southgate, Senju, & Csibra, 2007).
Many perspective taking measures evaluate non-motor aspects of perspective such as another’s emotions, general intentions, or what objects are in his/her line of sight (Pearson, Ropar, & Hamilton, 2013). Some recent research, however, indicates that individuals with ASD may be able to more-readily perceive the intentions of another person if those intentions are conveyed motorically (e.g., through motor actions; Alderidge, Stone, Sweeney, & Bower, 2000; Gonzalez, Glazebrook, Studenka, & Lyons, 2013). Recently, adults with ASD demonstrated the ability to facilitate the actions of another individual during a social-motor interaction that involved handing a tool to another person in a manner that facilitated its use (Gonzalez et al., 2013). Specifically, participants were asked to hand the experimenter a hammer for the purpose of hammering a peg. For some trials, facilitating the examiner’s use of the hammer involved turning it around so that the handle was easily graspable. Although this task involved verbal commands such as “help me hammer,” facilitation of the experimenter’s hammering relied on the ability of the participant to consider the experimenter’s perspective in which it would be best to receive the hammer by the handle rather than by the hammerhead. In other words, grasping the tool initially in an uncomfortable manner to facilitate the experimenter’s grasp was a motoric demonstration of the participant’s ability to take the examiner’s perspective. Individuals with ASD facilitated the experimenter’s grasp only 65-73% of the time (Gonzalez, Glazebrook, Studenka, & Lyons, 2013) as compared to neurotypical participants who facilitated the examiner’s grasp 80-97% of the time (Gonzalez, Studenka, Glazebrook, & Lyons, 2011).

Furthermore, Scharoun & Bryden (2016) asked a similar question using the functional task of lifting a cup and handing it to a researcher to facilitate pouring water. The posture with which children handed the glass to the researcher did not differ between those with ASD and neurotypical children suggesting either that children were familiar enough with cups that planning was not sufficiently taxed, or that perspective taking, and therefore, motor planning, was facilitated via motor actions. In both of these paradigms, the inference of perspective is based on social interaction, which may involve visual attention and visual perspective taking.

Visual perspective is typically assessed in two ways. Level 1 visual perspective tasks assess a participant’s ability to judge what another person is looking at. Level 2 visual perspective tasks assess a participant’s ability to judge what another person is looking at and how that person might see the object differently than him/herself (Flavell, 1974, 1978). Individuals with ASD have particular difficulty with level 2
perspective taking (Hamilton, Brindley, & Frith, 2009; Pearson, Ropar, & Hamilton, 2013). It is possible that visual perspective taking is a necessary component of understanding how another person might need to grasp an object, and therefore, a lack of visual perspective taking on either level might pre-dispose an individual to hand an object in a way that does not facilitate the action of the experimenter. In other words, in the social-interaction task above, those with ASD may be unable to visualize the tool from the experimenter’s perspective, and therefore, may have trouble understanding how the experimenter may need/want to grasp an object, leading to poorer motor perspective taking and less helpful interactions.

Perspective taking plays an important role in language development in typical children (Comparini, Douglas, & Perez, 2014; Nurmsoo & Bloom, 2008; San Juan, Khu, & Graham, 2015) as well as in children with ASD (Hamilton et al., 2009; Volden, Mulcahy, & Holdgrafer, 1997). However, as described above, perspective taking in social-motor interaction has only been explored in high functioning adults with ASD who have more general motor and social experience than children with ASD, and in a group of children using a task that may have elicited a habitual response rather than testing motor planning (Scharoun & Bryden, 2016). Furthermore, although motor impairments are considered key features of ASD, they are not currently included as diagnostic criteria, nor is the potential impact of motor impairment on social communication and interaction fully understood. Deficits in understanding the plans of others may be directly related to deficits in motor control and planning within an individual. In addition to general impairment with gross and fine motor control and coordination (Fournier, Hass, Naik, Lodha, & Cauraugh, 2010; Manjiviona & Prior, 1995; Ming, Brimacombe, & Wagner, 2007), individuals with ASD also have demonstrated differences in motor planning. One typical experimental paradigm used to measure motor planning is the end-state comfort effect. End-state comfort refers to the observation that individuals sometimes choose awkward or uncomfortable initial postures to ensure comfort at final postures (e.g., grasping a cup with a thumb down grasp in order to end with a thumb-up, more comfortable, posture for pouring; Rosenbaum, et al., 1990). A review of end-state comfort in typically developing children revealed an increase in adoption of end-state comfort from 3 – 12 years of age in typically developing children (Wunsch et al., 2013). Less adoption of end-state comfort in children with ASD (28% compared to 71% in ten year olds) was shown by Hughes (1996) using a bar transport task.
similar to the social-motor task described above. In this experiment, participants grasped a wooden dowel rod with either an underhand or overhand grasp and placed one end into a target. A thumb-up posture when the dowel was placed into the target was considered a “comfortable” end-state.

Two experiments report no difference between children with ASD and controls. One experiment measured end-state comfort in a task involving rotation of a disk (Van Swieten et al., 2010). In both a neurotypical and an ASD group of children, comfortable end-state postures were only adopted 50% of the time, seemingly pointing to no impairment of planning in children with ASD, however, in this task, subjects were instructed to always grasp the object with their thumb toward the red end of the dowel and were then instructed to rotate the disk in either a clockwise or counterclockwise direction. In this case, both the beginning and end-state postures were specified, and therefore were not a true test of motor planning. The 50% adoption of end-state comfort were a function of the experimental design rather than of participant’s grasp choices to complete the task. Another study reported no difference between the beginning and end-state comfort adopted by children with and without ASD (Hamilton et al., year). In this study, children grasped a wooden dowel with either an under or an overhand grasp and placed a specified end into a target location (see Rosenbaum et al., 1990). Children with and without ASD made the same number of grasp “errors” – specified as a beginning-state grasp that did not lead to end-state comfort – indicating no motor planning impairment in children with ASD. In this study, however, the control group of children was matched to the ASD group based on verbal mental age and were on average 4 years old, while the group of children with ASD were 8 years old on average. These results indicate that 8 year old children with ASD plan motor tasks equivalent to 4 year old typically developing children, and potentially, that performance on this end-state comfort task is related more to verbal mental age than chronological age. It is of note that in most dowel rotation tasks, verbal instructions are given related to the task goal, and therefore verbal understanding may influence task performance.

Because of the potential impact of early assessment and detection of ASD based on non-verbal measures of perspective taking, the purpose of this study was to compare the ability of neurotypical children and children with ASD to take on the perspective of another person during a social-motor interaction task. Furthermore, we aimed to explore the relationship between verbal and motor measures of perspective taking as well as changes in motor perspective taking over time. Data were collected from
children with ASD who were participating in a language intervention program (Gillam, Hartzheim, Studenka, Simonsmeier, & Gillam, 2015). Each week, experimenters measured the use of mental and linguistic verbs in children’s narration and the ratio of facilitation (handing the object in a manner that facilitated hammering) over non-facilitation during the social-motor interaction. We hypothesized that children with ASD would exhibit less perspective taking during social-motor interaction than neurotypical children. We further hypothesized that improvements in verbal perspective taking would correspond with improvements in motor perspective taking.

Methods

Participants

Five children diagnosed with ASD, were recruited to participate in the narrative intervention and the social-motor interaction task. Five verbally matched control children were recruited to participate only in the social-motor interaction task. These children were age matched to within 12 months and gender matched to the child with ASD, and showed no educational, social or physical disabilities. Participants with ASD were monolingual English speakers with an educational diagnosis of autism (they had been diagnosed by educators and special educators). All children were reported to prefer to use their right hands for daily tasks such as writing and using a fork (parent report). All children had standard scores of 70 or above on the screening portion of the Universal Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998) which is a measure of reasoning ability. They were characterized as, “verbally fluent” on the Autism Diagnostic Observation Schedule (ADOS-2: Lord et al., 2012). The Autism Diagnostic Observation Schedule (ADOS-2) is a measure of verbal communication and social interaction that assesses the use of language to provide information about events outside of the immediate context, and the extent to which children produce logical connections within sentences (e.g., using but or though). Four of the children earned standard scores at or below 85 on the Comprehensive Evaluation of Language Fundamentals-4 (Semel, Wiig, & Secord, 2003). The CELF-4 is a measure of general language proficiency and includes subtest scores for receptive and expressive language. These scores are combined for a core composite score. One child with ASD had CELF-4 scores above average (114), but her stories lacked organization, coherence or cohesiveness. None of the children were observed to
use cognitive and linguistic verbs related to perspective taking (e.g., decided, thought) in their narratives prior to the onset of the study.

Descriptives including age, gender, nonverbal IQ and verbal scores are listed in Table 1. Participants were divided into two sets for the purpose of the multiple baseline single-subject design. The first participant in each set received treatment while the second (or third participant in the case of set 1) stayed in baseline. The second participant started intervention after the first participant made significant progress. The participants in set 1 generally scored higher on all measures; those in set 2 scored lower, indicating these children had lower overall intelligence and verbal ability.

---Insert table 1 about here---

**Materials and Setting**

**Verbal perspective taking.** Participants with ASD participated in a narrative intervention program that was designed to improve their ability to answer questions about stories and to tell coherent, complete stories (see Gillam et al., 2015). Before, during and after their intervention sessions, children were asked to create and tell stories about static pictures. Their use of mental state language was summarized by a Perspective Taking Index (PTI) that characterized the use of mental state and causal language in children’s narratives. This perspective taking index, described in more detail below, is part of a larger rubric called Monitoring Indicators of Scholarly Language (Gillam & Gillam, 2013). The use of words such as *thought* and *decided* or explicit statement of the internal responses and plans of characters provides evidence that a child has the ability to attribute mental states to others. Causal language (e.g., because, so that, in order to) is used to connect events in stories and to provide temporal links between them and infers the ability to understand relationships between characters that may hold differing perspectives. None of the children used words to indicate the mental states of others or to indicate causality in their stories during the baseline period before the onset of intervention.

**Motor perspective taking.** For the social-motor interaction task, (see Figure 1) the participant and experimenter sat across from each other at a 64 cm tall table. A small wooden toolbox and a set of 8 wooden pegs were placed in front of the experimenter approximately 30 cm apart. Two tools were used; a wooden dowel (18.5 cm x 2 3/10 cm diameter) and a wooden hammer (18.5 cm x 2 cm diameter on the handle). The dowel was used in addition to the hammer based on findings that adults with ASD facilitate
the experimenter’s grasp more often when using the dowel (73 vs. 65%; Gonzalez et al., 2013). Trials where the dowel was used to hammer were purportedly more facilitated because the dowel had no end that was specified as a handle, and therefore, it may have been easier to override the inclination to grasp the end of the object that did not facilitate the experimenter’s grasp. For example, if the handle of the hammer were grasped initially, the handle could, then, not be handed to the experimenter. Two different color combinations for the objects were used (black/white and red/blue) to form three different colors for the hammering end of the object: white, black, or red. This was to ensure that participants responded to the properties of the objects (e.g., the handle is easier to hold) rather than developed rules for grasping based on color (e.g., I should grasp the black end of the object). The head of the hammer (6.5 x 2.5 cm) and part of the handle (7.25 cm) or ½ of the stick (9.25 cm) was painted either black, red, or white with the other half painted white, blue, or black respectively. Two sticky notes were placed 43.5 cm apart on the participant-side of the table. A small circular sticker, placed 18 cm from the edge of the table and centered between the sticky notes, served as a guide for the placement of the center of the object prior to each trial. A camera was placed above the participant, looking down, in order to record grasp postures for later coding.

| Experimental Design |

The experimental conditions included the following independent variables: objects (2 levels: dowel vs. hammer), object orientation (4 levels: hammer head up, right, left, or down), peg placement (2 levels: left vs. right with respect to the participant), and action (2 levels: hammer vs. put it away). The dependent variable was how often a participant facilitated the grasp of the experimenter on trials where some facilitation was warranted.

| Procedure |

At the beginning of testing, participants completed 32 trials, which lasted about 10-15 minutes. Following a few noncompliant sessions with one child, the daily protocol was shortened to 16 trials, which lasted between 5 and 8 minutes. The 16 trials included all tasks with the exception that the placement of the pegs (on the right or left) alternated every four trials and the counterbalanced order was performed on a different day. All social-motor interaction tasks were performed once per week, following the narrative
intervention session. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Utah State University Institutional Review Board. Informed consent and/or assent was obtained from all individual participants included in the study.

Verbal perspective taking. Participants came in for 19-33 sessions of narrative training. This narrative training, Supporting Knowledge in Language and Literacy (SKILL), was administered by a group of researchers in the department of Communicative Disorders and Deaf Education, and was originally designed for use with children who were at risk for language impairment (S. L. Gillam, Olszewski, Fargo, & Gillam, 2014). Four children with ASD and all neurotypical children were administered the training in a quiet testing room in a university building. One child with ASD was administered the training in a quiet classroom at his elementary school, after hours. For further details on the narrative training administered to these children see (Gillam et al., 2015). During the narrative intervention, children were seen individually, twice weekly, for 50-minute sessions designed to improve their narrative comprehension and production skills. During instruction, children practiced identifying feelings, internal responses and reactions of characters to the events that occurred in stories told to them, and in stories they created on their own. They also practiced using causal language to connect the events and internal responses in stories (e.g., They ran because they were afraid the aliens would get them). These stories were recorded and transcribed into C-units (Loban, 1976) using Systematic Analysis of Language Transcripts (SALT; Miller, Iglesias, & Nockerts, 2004) transcription conventions. A C-unit consisted of an independent main clause and any phrase(s) or clause(s) subordinated to it. A research assistant, blind to the purpose of the study, transcribed the stories; a second research assistant checked each transcript for accuracy. Each transcript was checked for words, spelling, mazing, morpheme segmentation and utterance segmentation. Any discrepancies were resolved through consensus. Word-by-word reliability for the transcripts was 96% for C-unit segmentation.

The Monitoring Indicators of Scholarly Language (MISL) rubric was used to measure improvement in knowledge of story structure and in perspective taking (Gillam & Gillam, 2013). A perspective-taking index (PTI) was calculated by adding scores earned for internal response (0-3), plan (0-3), mental (0-3) and linguistic verbs (0-3). An internal response was a feeling or reaction by the character that was prompted by an event in the story. For example, the child might state, “The boy was
afraid because the bear was running toward him.” For plan, a child might state, “He decided to run away from the bear so he wouldn’t be eaten.” For internal response and plan, scores of 0 indicated that the language feature was not present; a score of 1 indicated that the feature was emerging; a score of 2 indicated that the feature was present and causally linked to the other elements in the story using words like because and so; and a score of 3 indicated that the child demonstrated full mastery and use of the concept in a causal framework.

Examples of mental verbs include “thought, decided, and wanted.” Linguistic verbs include words such as “yelled, screamed, and said.” Scores of 0 indicated that the linguistic form was not used. Scores of 1 indicated that at least 1 exemplar was present; scores of 2 indicated that there were 2 different exemplars present; and scores of 3 indicated that there were 3 different exemplars of the linguistic form present.

The second author and a research assistant independently scored 20% of the de-identified transcripts of the narratives told by participants using the PTI subscore from the MISL rubric. The inter-rater reliability scores for the perspective-taking index was 97%. For more information about the narrative intervention and the scoring procedures for the MISL, see Gillam et al., (2015).

Motor perspective taking. Participants completed between 14-18 sessions of the motor perspective-taking task. Control participants came in for three sessions of the motor perspective-taking task. For participants with ASD, the motor task was conducted once weekly immediately following a narrative instruction session. In 16 instances, a participant could not stay for the motor testing and came in on another day in the same week (see Figures 5 & 6). No motor tasks were discussed or taught during the narrative intervention session. For each session, the participant met the experimenter in a room different from the one used for the narrative training, sat down across from the experimenter, and placed his or her hands on two sticky notes. The experimenter was either the main author or one of her students. Each child became familiar with the student who tested him or her, and, additionally, the main author was present for every testing session. The camera was turned on, and testing began. The experimenter placed the toolbox and the 8 pegs in the appropriate position, placed the tool in the appropriate orientation in front of the participant, made sure the participant was ready, and then gave a command. The command was either “help me put it away” or “help me hammer”. For the hammer
condition with the dowel rod, the experimenter said “help me hammer with the black end”, “help me hammer with the white end”, or “help me hammer with the red end” depending on the color used for the day. For all trials on one day, the color for hammering remained consistent. The experimenter gestured (always with the right hand) in a hammering or a put-away motion concurrent with verbalizing the word “hammer” or “put” and then held his or her right hand palm up, between the toolbox and pegs, with the V between the thumb and fingers toward the participant (see Figure 1). The experimenter’s were trained to perform this task in the same manner every time. Additionally, the experimenters were trained to hold the hand in place, and not to reach for the object, but to wait until the child handed the object to him/her. The experimenter’s left hand rested in his or her lap. The experimenter then waited until the participant handed the object to him or her.

Once the object was placed into the experimenter’s hand, he or she either hammered one peg with it, or placed the object into the toolbox. In the case where the trial specified the researcher hammer, but the hammer or stick was handed in a way that did not directly afford hammering, the researcher deliberately turned the object around by placing it first into his/her left hand, and then back into his/her right hand in the correct orientation for hammering. Other than turning the object around to complete the hammering action, no emphasis was given to the action (e.g., no shrugging or sighing etc...). In other words, a participant received no feedback as to whether or not he or she had performed the task “correctly”. The experimenter then brought the right hand back to rest in his/her lap before beginning the next trial. Following the completion of one trial, the experimenter moved to the next task, placing the pegs and the toolbox on the specified sides, and placing the next object in the specified orientation in front of the participant.

No feedback or instruction was given to participants at any time. In cases where a participant was not paying attention, or not focused on the task, the experimenter reminded the participant to “sit up straight”, “put your hands on the sticky note”, and “get ready for the next trial”. Participant 005 exhibited the most difficulty paying attention and staying on task. For this participant, we modified the instructions to simulate different situations (e.g., “we’re building a rocket ship, and to get the ship to take off, we need to hammer all of the pegs”). The specific verbal instructions, “Help me hammer” or “Help me put it away” remained the same.
Data Analysis

**Verbal perspective taking.** Verbal perspective taking was assessed by measuring the perspective-taking qualities of children’s narrative language. To obtain the Perspective-taking Index (PTI), we summed scores on the MISL narrative scoring rubric related to the use of internal response, plans, mental and linguistic verbs. Each column was worth a total of 3 points for a combined possible total of 12 points. A minimum criteria for the PTI was set at 6, which indicated that the student demonstrated mastery by scoring 2 or greater on each of the sub-scores used to calculate PTI. For example, internal response = 2; plan = 2 and mental verb use = 2.

**Motor perspective taking.** Motor perspective taking was assessed using the ratio of facilitation, which indicated how often a participant facilitated the grasp of the experimenter on trials where some facilitation was warranted. This ratio was calculated as the number of times a participant handed the object to the experimenter in a way that directly facilitated hammering divided by the number of trials (the ratio score) when manipulation would have been required by either the participant or the experimenter. In other words, trials in which the hammering end of the object was easier to grasp required either the participant or the experimenter to turn the object around in order for the experimenter to use it (Figure 2). For a participant who preferred using the right-hand for this task, the hammering end of the object facing away from or to the left would necessitate an object rotation at some point (see Figure 4) when the goal of the experimenter was to hammer the pegs. For each participant, hand preference during the task was determined by the number of trials, over the entire experiment, one hand was used over another hand. Participants 001, 002, 004 and 005 used their right hand a majority of the time for grasping the object. Participant 003 used her left hand a majority of the time. Control participant 006 used his left hand a majority of the time, but 007, 008, 009 and 010 used their right hands a majority of the time.

In order to understand how children were planning actions, particularly when no experimenter facilitation was required, we measured the overall ratio of how often participants manipulated the object while handing it to the experimenter. Manipulation was noted any time a participant’s beginning-state comfort (the posture they adopted when grasping the object) differed from his/her end-state comfort (the posture present when the object was placed into the experimenter’s hand).
For the grasp ratings, grasps of “in” or “up” were rated as comfortable, and grasps of “down” or “out” was rated as uncomfortable (see Coelho, Studenka, & Rosenbaum, 2014; Rosenbaum et al., 1990). For the ratio of facilitation, a 1 was given for a score of “yes” indicating that the participant handed the object in a way that led to no need for experimenter manipulation. If only a minor manipulation was needed in order to perform the hammering action, a .5 score was given indicating that the experimenter’s action was facilitated, but not fully. An example of a minor manipulation was one where the tool was handed to the experimenter in the correct orientation, but the position was off (e.g., only a small portion of the handle contacted the experimenter’s hand). In this case, the experimenter made a minor adjustment (i.e., adjusted the object with his/her left hand so that his/her hand was holding a majority of the handle). Only trials in which the experimenter used the object to hammer could have a score other than 0.

**Inter-Observer Agreement**

Coding of grasp comfort and the presence of facilitation (e.g., no experimenter manipulation) was performed post-hoc via video analysis. Two experimenters trained in observational coding techniques scored each trial independently for the comfort of the participant’s initial and final grasps on the object, as well as the presence of experimenter manipulation (see Figures 3 & 4). It is common in experiments that utilize multiple observers to code participant behaviors to compare the agreement of scores across raters (Jongbloed-Pereboom, Nijhuis-van der Sanden, Sararer-Schiphorst, Crajé, & Steenbergen, 2013; Knudsen, Henning, Wunsch, Weigelt, & Aschersleben, 2012; Wilmot & Byrne, 2014). In light of this, inter-rater reliability scores were calculated for each participant and across groups (ASD, neurotypical). Overall, Observer 1 and Observer 2 agreed on 1861 of 1904 trials for the beginning state grasp, resulting in an inter-rater reliability of .98. Observers agreed on 1837 of 1904 trials for the end state grasp, resulting in an inter-rater reliability of .96. Finally, observers agreed on 1880 of 1904 trials for experimenter manipulation, resulting in an inter-rater reliability of .98.

Within-subject reliabilities ranged from .95 to 1 within the ASD group ($M = .98$) and from .79 to 1 ($M = .95$) within the control group for the beginning-state grasp, from .90 to 1 within the ASD group ($M = .97$) and from .81 to 1 ($M = .93$) within the control group for the end-state grasp, and from .97 to 1 within the ASD group ($M = .99$) and from .95 to 1 ($M = .99$) within the control group for experimenter
These relatively high reliabilities are consistent with other ratings of grasp position in children (e.g., Knudsen et al., 2012; Wilmot & Byrne, 2014). In the case where responses were in conflict, coders’ decisions were re-evaluated in light of the pre-established decision tree. Both scorers together came to consensus regarding which outcome was most appropriate. The coders were not blind to the purpose of the experiment, however, decision trees aimed to keep the coding of grasp postures as objective as possible (see Figure 3 and 4).

Results

The purpose of this study was to explore the extent to which verbal and motor planning behaviors were related for children with and without ASD. Our results support a functional relationship between verbal and motor perspective taking. We compared a measure of verbal perspective taking (PTI) to a measure of motor perspective taking (the ratio of facilitation over non-facilitation). The main variable reflecting motor perspective taking was the ratio of trials for which a participant facilitated the experimenter’s grasp to trials where the experimenter’s grasp was not facilitated when some manipulation was needed (e.g., trials where the object handle was initially facing toward the participant or away from the participant’s dominant hand, Figure 2). These ratios were plotted along with the verbal Perspective Taking Index (PTI). For control participants, only the ratio of facilitation was measured. Ratio of facilitation is plotted over time with sessions on the x-axis. In Figure 5, for example, the participant completed four weeks of baseline testing, then received the narrative intervention. Each tick mark represents time points at which the participant was trained and tested on the narrative intervention and/or tested on the cooperative perspective taking task. Figure 9 represents the ratio of facilitation for five neurotypical control participants who underwent three days of the motor perspective-taking task, but did not undergo the narrative intervention.

Tau-U was calculated for the PTI scores and the ratio of facilitation for each participant. Tau-U is an index of change in the level from baseline to treatment phases that takes into consideration the “trend” within the intervention phase. It gives you a probability value (< .05) and may be interpreted like an effect
Mean and standard deviation for baseline and treatment phases as well as percent change from baseline to treatment are presented for PTI and ratio of facilitation for each participant in Table 2.

Participant 001 reached a PTI score at or above 6 on session 8 of the narrative intervention and reached a facilitation ratio of 1 on session 6 of the motor perspective-taking task (Figure 5). This subject maintained a facilitation ratio of 1 (indicating she turned the object around to facilitate the experimenter’s hammering 100% of the time) on all of the remaining experimental sessions. The Tau-U for the PTI score for participant 001 was .73 ($p = .02$), indicating that this participant’s narrative skill significantly improved from baseline to testing sessions. The Tau-U score for the ratio of facilitation was .93 ($p = .02$) indicating facilitation also improved from baseline to testing sessions.

Participant 003 reached a PTI score of 6 on session 15 of the narrative intervention and reached a facilitation ratio of 1 on session 7 of the motor perspective-taking task. This subject did not maintain a facilitation ratio of 1, but stayed at or above 50% on all of the remaining experimental sessions. The Tau-U for the PTI score for participant 003 was .75 ($p = .003$), indicating that this participant’s narrative skill significantly improved from baseline to testing sessions. The Tau-U score for the ratio of facilitation was .75 ($p = .02$) indicating facilitation also improved from baseline to testing sessions.

Participant 004 reached a PTI score at or above 6 on session 13 of the narrative intervention and reached a facilitation ratio of 1 on session 4 of the motor perspective-taking task. This subject did not maintain a facilitation ratio of 1, but stayed at or above 50% on all of the remaining experimental sessions. The Tau-U for the PTI score for participant 004 was .84 ($p = .002$), indicating that this participant’s narrative skill significantly improved from baseline to testing sessions. The Tau-U score for the ratio of facilitation was .56 ($p = .1$) indicating facilitation did not significantly improve from baseline to testing sessions.

Figure 6 depicts participants from group 2, who did not reach a ratio of facilitation of 1, and who did not exhibit improvement on the narrative intervention task. Participant 002 reached a PTI score at or above 6 on session 13 of the narrative intervention but never reached a facilitation ratio of 1 on the motor perspective-taking task. On the last three sessions of the motor perspective-taking task, this participant
adopted a strategy of handing the object as quickly as possible, leading to a ratio of 0. The Tau-U for the PTI score for participant 002 was .40 ($p = .23$), indicating that this participant’s narrative skill did not significantly improve from baseline to testing sessions. The Tau-U score for the ratio of facilitation was .47 ($p = .3$) indicating facilitation did not significantly improve from baseline to testing sessions.

Participant 005 never reached a PTI score at or above 6 of the narrative intervention and only had a ratio at or above 50% on the motor perspective-taking task twice. The Tau-U for the PTI score for participant 002 was .31 ($p = .21$), indicating that this participant’s narrative skill did not significantly improve from baseline to testing sessions. The Tau-U score for the ratio of facilitation was .07 ($p = .83$) indicating facilitation did not significantly improve from baseline to testing sessions.

The group of control participants (006-010) were only tested on the motor perspective-taking task. Every participant reached a facilitation ratio of 1 by the third session (Figure 7). Only one session (the first for subject 008 was below 50%).

The language intervention protocol was conducted according to a multiple baseline across participants design, which enabled us to assess changes in motor planning as a function of language intervention. We were also interested in whether or not the children with ASD differed from the neurotypical control children regarding ratio of facilitation. In addition, we were interested in the ratio of experimenter manipulation to no manipulation during trials where manipulation was not needed. Lastly, we were interested in whether or not the object that children handled (dowel rod vs hammer) had an effect on their ability to facilitate the experimenter’s action. Therefore, t-tests and ANOVA’s were conducted where appropriate on the dependent measures of ratio of facilitation and ratio of facilitation based on the object used. In addition, the ratio of trials where the object was manipulated was evaluated for trials that necessitated a manipulation and trials that did not. For the ratio of facilitation, all 5 control children reached a ratio of 1 on the final testing session, therefore individual t-tests were used to compare facilitation ratio between children with ASD on the first and last session, and neurotypical control subjects on the first session. There was a significant difference, $t(8) = -4.67$, $p = .0016$, $d = 2.97$, $1-\beta = .98$, between the initial values of ratio of facilitation for children with ASD ($2 \pm .14$) and neurotypical control.
children (.64 ± .16; see Figure 8) indicating that children with ASD exhibited impairment in motor perspective taking over neurotypical control children. However, there was no significant difference between the final facilitation ratio of children with ASD (.5 ± .4), and the first facilitation ratio of neurotypical control children, \( t(8) = -.7, p = .48, d = .46, 1-\beta = .1 \), suggesting that, following the narrative intervention, and/or practice at performing the motor task, children with ASD reached levels of neurotypical motor perspective taking.

We hypothesized that the dowel rod might have a more neutral affordance (e.g., it had no end that afforded grasping more than hammering) that could aid a participant in choosing a more awkward initial posture in order to facilitate a more comfortable experimenter posture. Because the last session for the neurotypical group reached a ceiling of 1 with no variance, an ANOVA was run on only the ASD group using session (first vs. last) and object (dowel vs. hammer) as factors. The initial ratio of facilitation for children with ASD on trials that required some manipulation and the object of the hammer was .1 (±.14), whereas the ratio of facilitation when using the dowel rod was .2 (±.21). Although this ratio of facilitation was slightly larger for the dowel rod, it was not significant (see Figure 9).

Lastly, we wanted to know if children with ASD differed from neurotypical children on the extent to which they manipulated the object on trials where no manipulation was needed (non-crucial trials; see Figure 10). Manipulations were scored as anytime the initial and final grasp of a participant differed in terms of comfort (e.g., the initial grasp was comfortable, but the grasp just prior to handing the object to the experimenter was uncomfortable).

In order to test the difference between children with ASD and neurotypical control children for ratio of manipulation on non-crucial trials, an ANOVA was run using group (ASD vs. control) and session (first vs. last) as factors. A significant main effect of group, \( F(1,8) = 13.75, p = .006, \eta^2_p = .84 \), reflected the greater ratio of manipulation for neurotypical control children (.43) as compared with children with ASD (.20). No significant main effect of session was seen, however, a significant group by session interaction, \( F(1,8) = 15.04, p = .005, \eta^2_p = .87 \), supported the observation that children with ASD exhibited a decrease
in their ratio of manipulation from the first to the last session, whereas, neurotypical control children exhibited an increase in their ratio of manipulation. Because this manipulation was measured for trials that did not require manipulation, we believe the decrease in manipulation seen in children with ASD reflects greater understanding of the task. The increase in manipulation on non-crucial trails for control participants may reflect greater flexibility of motor planning.

**Discussion**

The overall aim of this study was to identify the extent to which children with ASD were able to facilitate an experimenter’s grasp during a social-motor perspective-taking task, and the extent to which children’s verbal perspective-taking ability was associated with motor perspective-taking ability. **Our main hypothesis that children with ASD would exhibit less perspective taking during social-motor interaction than neurotypical children was supported.** We documented that, similar to high functioning adults with ASD (Gonzalez et al., 2013), children with ASD exhibited difficulties understanding the perspective of another individual as reflected by the lack of mental and linguistic verbs in their oral narratives and by their lower ability to facilitate motor actions during social-motor interactions. Most importantly, we documented improvements in verbal perspective taking along with improvements in motor perspective taking. **More specifically, children who showed improvement on the PTI (values above the cutoff of 6), also reached 100% helping behavior, whereas children who did not show improvement in the PTI did not reach 100% helping behavior.**

**Our second hypothesis, that improvements in verbal perspective taking would correspond with improvements in motor perspective taking, was also supported.** Improvements in both verbal and motor perspective taking were seen for four of five children, while one child exhibited minimal improvement in verbal and motor perspective taking. Even though not all children with ASD facilitated the action of the experimenter 100% of the time, all children did exhibit improvement in facilitation. The least improvement was shown by participant 005, who facilitated 0% at the beginning and above 20% by the end of testing. This variability in our findings across subjects reflects the high degree of variability in populations with Autism (Lecavalier, 2014).

Neurotypical children who completed our motor perspective-taking task varied in how often they facilitated on the first and second sessions, but all facilitated 100% of the time by the third session. One
child with ASD reached 100% facilitation behavior on the fourth session, one on the sixth, and one on the seventh session. Two children with ASD never reached 100% facilitation behavior. For four participants, although maximal facilitation ratios were reached, they were not maintained at 100% for the rest of the sessions. For example, participant 004 facilitated the experimenter’s action 100% of the time for one session, but then only 70% of the time for the following session. This finding showcases the high variability in behavior of children with ASD. In addition, the two children with ASD who never reached 100% facilitation behavior were the two subjects who had the lowest nonverbal reasoning ability (UNIT), and CELF-4 scores. Interestingly, non-verbal IQ has been directly related to motor impairment symptoms in individuals with ASD (Dziuk et al., 2007).

The documented difficulties of children with ASD related to understanding and interacting with the actions of other people may stem from differences in planning and executing their own actions (see Ní Choisdealbha & Reid, 2014 for a review of this hypothesis). In tasks that require the grasp and manipulation of an object, children and adults with ASD exhibit less end-state comfort than age-matched controls (Hughes, 1996; Simermeyer & Ketcham, 2015), and perform on par with verbal metal age matched controls (Hamilton, Brindley, & Frith, 2007). End-state comfort refers to the observation that individuals sometimes choose awkward or uncomfortable initial postures to ensure comfort at final postures (e.g., grasping a cup with a thumb down grasp in order to end with a thumb-up, more comfortable, posture for pouring). Less end-state comfort in children with ASD suggests that they may not weigh the costs associated with discomfort the same way as those without ASD. This might impair understanding the associated cost incurred by the experimenter of having to turn an object around if it is not handed over in an appropriate way to facilitate a future action.

Children with ASD also display a lack of anticipation of upcoming actions, demonstrating differences in organizing actions that occur in sequence (Cattaneo et al., 2007; Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). In other words, children with ASD may plan each action separately, explaining why postural comfort had less influence on movement planning and why children sometimes failed to plan appropriately for the upcoming action of another individual. In our study, this was demonstrated by the inconsistency in which an object was grasped appropriately (first action), so that it could be turned around to hand it to the experimenter (2nd action) appropriately for the intended goal of hammering (3rd action).
Differences in planning actions sequentially may impact the perception of others’ motor actions as well as delay the execution of one’s own actions, leading to difficulties in motor interaction.

There is some research suggesting that, in order to understand the actions of another individual, the neural mechanisms responsible for performing these same actions must be active (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Ní Choisdealbha & Reid, 2014; Rizzolatti, 2005; Rizzolatti & Craighero, 2004). The most compelling evidence that the mirror neuron system is impaired in individuals with ASD comes from neural activation studies showing differences in the way individuals with ASD perceive other’s motor acts. For example, Oberman and colleagues (2005) examined brain activation during action performance and observation using EEG technology. Neurotypical individuals exhibited mu wave (brain oscillations between 9 and 11 Hz) suppression upon both execution of a motor action and observation of that same motor action performed by another person. Individuals with ASD exhibited mu wave suppression when performing motor actions, but not when observing others performing actions (Oberman et al., 2005). Furthermore, using a technique that stimulates the motor cortex of the brain using electrical currents (TMS), induced hand movements became more pronounced when neurotypical participants were watching videos of the same hand movements. The effect of videos on motor activation was much weaker in a group of individuals with ASD (Théoret et al., 2005). These studies collectively support the theory that individuals with ASD may exhibit impairment in understanding the intention of another person’s actions precisely because they cannot simulate those actions in their own mind.

The most compelling finding of our study was that the motor perspective-taking task mirrored the verbal perspective-taking task, indicating a relationship between perspective-taking in different domains. For children whose perspective-taking improved, two participants reached a PTI score of 6, indicating that they had sufficient knowledge and use of mental and linguistic verbs (maximum score possible = 12), within a session of when their facilitation ratio reached 1. For participant 002, who never reached a facilitation ratio of 1, the peak of both PTI and facilitation ratio scores occurred within a session of each other reflecting the link between motor and verbal perspective-taking even for lower functioning children. In support of the postulation that verbal and motor perspective-taking are linked, impairments in verbal communication often accompany impairments in motor control (e.g., pointing), indicating that difficulties in performing motor actions may impair early attempts at communication (Flaugnacco et al., 2014; Iverson &
Braddock, 2011; Owen & McKinlay, 1997; Peter & Stoe‐Gammon, 2008; Thomson & Goswami, 2008).

It is also possible, that improvements in verbal perspective taking influenced motor perspective taking via improving general language comprehension, attentional mechanisms, or verbal perspective taking. Because the social‐motor interaction task involved joint attention, visual perspective taking and verbal instruction, it is difficult to say what the specific link might be between verbal and motor perspective improvements.

**Limitations**

It is possible that motor impairment hampered an individual's ability to aid in a social‐motor task. Individuals with ASD are also more likely to exhibit speech and motor apraxia (Ming et al., 2007; Tierney et al., 2015) which might have impacted their ability to grasp objects similar to neurotypical children. Motor impairment may inhibit an individual's ability to simulate movements similar to another individual, thus making third‐order planning (planning for another's actions) difficult. Motor impairment may also mean that children with ASD perform motor tasks differently regardless of the ability to understand what another individual would like to do with an object. In addition, autism severity was not measured in these individuals. It is possible that differences in linguistic and motor perspective taking were related to autism severity. Lastly, due to the longitudinal nature of this motor study paired with the language intervention, our sample size was small which increases variability in terms of language and cognitive abilities. Further work should look at a larger sample of participants including Autism severity, cognitive and language assessments.

**Implications**

Recent literature supports that atypical movement characteristics may be observed in children who are at‐risk for ASD much earlier than verbal deficiencies can be assessed (as early as 6 mos of age; Kaur, Srinivasan, & Bhat, 2015). It stands to reason that motor deficits exhibited by those with ASD may impact the understanding and performance of communicative actions (Fabbri‐Destro, Gizzonio, & Avanzini, 2013; Iacoboni et al., 2005). More specifically, if children with ASD do not perform motor actions in the same way as others, they may not receive appropriate motor‐initiated nonverbal responses from adults and or other children, leading to fewer and poorer communicative interactions. Therefore, these differences in both movement perception and production in individuals with ASD should not be
overlooked (Piochon et al., 2014). Evaluation of how an individual selects motor actions to facilitate the actions of another person may be an informative, implicit way to measure perspective taking, particularly in children who may be non-verbal. Furthermore, examination of motor interaction could potentially allow practitioners to assess a child’s ability to take on the perspectives of another person earlier than verbal assessments can be performed. Lastly, planning and execution differences and their impact on social-motor interaction could lend clues about potential mechanisms of improving social understanding and interaction in individuals with ASD. In many cases, this type of cooperative motor facilitation task may allow for measurement of perspective taking ability for children with ASD with more accuracy than typical verbal-based measures. In other words, many children may exhibit perspective taking, but not the linguistic markers needed to explicitly state perspective. Additional, non-verbal means of measuring perspective in individuals with ASD could potentially be used as means for earlier diagnoses and further differentiation of subtypes of ASD, and more targeted interventions aimed at improving social communication and interaction as a whole.
References


Figure Captions

Figure 1. Graphic of the experimental set up with the participant on the left and the experimenter on the right.

Figure 2. Object placements from the participant’s perspective. For a right-handed participant, object placements with the hammer head distal to the participant, or opposite of his/her dominant hand (c and d) would necessitate manipulation either by the participant or the experimenter when the trial required the experimenter to hammer. Object placements with the hammer-head proximal to or on the same side as the dominant hand (a and b) could be grasped, handed over, and used without manipulation.

Figure 3. The decision tree used for scoring beginning and end thumb position of the participant when the “hammer” end was black. When the object was not perpendicular or parallel to the participant, the experimenter made a judgment based on the closest orientation.

Figure 4. The decision tree used for scoring Experimenter manipulation.

Figure 5. Perspective Taking Index (PTI) scores (triangles) and ratio of facilitation to non-facilitation (circles) for participants 001 (a), 004 (b), & 003 (c). The color of the circles indicates the color of the end of the object used for hammering. Black indicates the black end was used, gray the red end, and white the white end.

Figure 6. Perspective Taking Index (PTI) scores (triangles) and ratio of facilitation to non-facilitation (circles) for participants 002 (a) & 005 (b). The color of the circles indicates the color of the end of the object used for hammering. Black indicates the black end was used, gray the red end, and white the white end.

Figure 7. Ratio of facilitation to non-facilitation for control participants over three sessions.
Figure 8. Ratio of facilitation to non-facilitation for trials that required manipulation for children with ASD and neurotypical control children on the first and last testing sessions. Error bars represent the standard error. The asterisk indicates a significant difference from the bar indicating the children with ASD on the first session.

Figure 9. Ratio of facilitation to non-facilitation for trials that required manipulation for both hammer and stick objects, and children with ASD and neurotypical control children on the first and last testing sessions. Error bars represent the standard error.

Figure 10. Ratio of manipulations made to no manipulations made on non-crucial trials (where no manipulation was required) for children with ASD and neurotypical control children on the first and last testing sessions. Error bars represent the standard error.
Figures

Figure 1 top
Figure 2 top

a

b

c

d
Figure 3 top

Grasp posture: object orientation when object is picked up or handed over.

- Are all fingers on one side of the object?
  - Yes: palm down? IN
  - No: palm up? OUT

- Are all fingers on one side of the object?
  - Yes: palm down? IN
  - No: palm up? OUT
Figure 4 top

experimentation adjustment

Did experimenter grasp non-hammer end only?

- no
  - Was the object in the correct orientation for hammering?
    - yes
      - minor manipulation "MINOR"
    - no
      - major manipulation "YES"
- yes
  - Was the object in the correct orientation for hammering?
    - yes
      - major manipulation "YES"
    - no
      - no manipulation "NO"
Figure 5 top
Figure 7 top

Subject 006
Subject 007
Subject 008
Subject 009
Subject 010
Figure 8 top
Figure 9 top

- Bar chart showing the ratio of facilitation for children with ASD and neurotypical control children.
- Comparison between the first and last session for hammer and dowel rod tasks.
- Error bars indicate variability in the data.
Table 1. Mean descriptives for all participants prior to participation in the intervention program

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (years; months)</th>
<th>Gender</th>
<th>CELF-4</th>
<th>UNIT</th>
<th>Matched Control Age (years; months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>10;8</td>
<td>Female</td>
<td>85</td>
<td>85</td>
<td>10;2</td>
</tr>
<tr>
<td>003</td>
<td>9;5</td>
<td>Female</td>
<td>114</td>
<td>115</td>
<td>8;5</td>
</tr>
<tr>
<td>004</td>
<td>8;4</td>
<td>Male</td>
<td>79</td>
<td>103</td>
<td>7;11</td>
</tr>
<tr>
<td>Set 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>002</td>
<td>10;9</td>
<td>Male</td>
<td>62</td>
<td>78</td>
<td>10;11</td>
</tr>
<tr>
<td>005</td>
<td>9;6</td>
<td>Male</td>
<td>48</td>
<td>91</td>
<td>9;2</td>
</tr>
</tbody>
</table>

CELF-4 represents Comprehensive Evaluation of Language Fundamentals; UNIT represents Universal Nonverbal intelligence Test.
Table 2. Mean, standard deviation, and percent change for Perspective taking index (PTI), and ratio of facilitation for each participant.

<table>
<thead>
<tr>
<th>Participant</th>
<th>PTI Baseline M (SD)</th>
<th>PTI Treatment M (SD)</th>
<th>% change</th>
<th>Ratio of facilitation Baseline M (SD)</th>
<th>Ratio of facilitation Treatment M (SD)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>1.80 (1.92)</td>
<td>6.25 (3.28)</td>
<td>247%</td>
<td>0.42 (.36)</td>
<td>0.93 (.16)</td>
<td>125%</td>
</tr>
<tr>
<td>004</td>
<td>1.22 (1.86)</td>
<td>5.82 (2.48)</td>
<td>377%</td>
<td>0.58 (.33)</td>
<td>0.79 (.15)</td>
<td>36%</td>
</tr>
<tr>
<td>003</td>
<td>2.42 (1.44)</td>
<td>5.70 (2.36)</td>
<td>136%</td>
<td>0.50 (.18)</td>
<td>0.82 (.22)</td>
<td>65%</td>
</tr>
<tr>
<td>Set 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>002</td>
<td>1.75 (1.26)</td>
<td>3.19 (2.69)</td>
<td>82%</td>
<td>0.31 (.09)</td>
<td>0.41 (.24)</td>
<td>32%</td>
</tr>
<tr>
<td>005</td>
<td>0.30 (0.67)</td>
<td>0.92 (1.12)</td>
<td>207%</td>
<td>0.18 (0.29)</td>
<td>0.15 (.17)</td>
<td>-16%</td>
</tr>
</tbody>
</table>
grasp posture

object orientation when object is picked up or handed over

are all fingers on one side of the object?

are all fingers on one side of the object?

yes no

palm down? palm up? palm in? palm out?

palm down? palm up? palm in? palm out?

IN OUT UP DOWN IN OUT
Did experimenter grasp non-hammer end only?

- **no**
  - Was the object in the correct orientation for hammering?
    - **yes**
      - minor manipulation “MINOR”
    - **no**
      - major manipulation “YES”

- **yes**
  - Was the object in the correct orientation for hammering?
    - **yes**
      - no manipulation “NO”
    - **no**
      - major manipulation “YES”
Table 1. Mean descriptives for all participants prior to participation in the intervention program

<table>
<thead>
<tr>
<th>Participant</th>
<th>Age (years; months)</th>
<th>Gender</th>
<th>CELF-4</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>10;8</td>
<td>Female</td>
<td>85</td>
<td>85</td>
</tr>
<tr>
<td>3</td>
<td>9;5</td>
<td>Female</td>
<td>114</td>
<td>115</td>
</tr>
<tr>
<td>4</td>
<td>8;4</td>
<td>Male</td>
<td>79</td>
<td>103</td>
</tr>
<tr>
<td>Set 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>10;9</td>
<td>Male</td>
<td>62</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>9;6</td>
<td>Male</td>
<td>48</td>
<td>91</td>
</tr>
</tbody>
</table>

CELF-4 represents Comprehensive Evaluation of Language Fundamentals; UNIT Universal Nonverbal intelligence Test.
Table 2. Mean, standard deviation, and percent change for Perspective taking index (PTI), and ratio of facilitation for each participant.

<table>
<thead>
<tr>
<th>Participant</th>
<th>PTI Baseline M (SD)</th>
<th>Treatment M (SD)</th>
<th>% change</th>
<th>PTI Baseline M (SD)</th>
<th>Treatment M (SD)</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Set 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>001</td>
<td>1.80 (1.92)</td>
<td>6.25 (3.28)</td>
<td>247%</td>
<td>0.42 (.36)</td>
<td>0.93 (.16)</td>
<td>125%</td>
</tr>
<tr>
<td>004</td>
<td>1.22 (1.86)</td>
<td>5.82 (2.48)</td>
<td>377%</td>
<td>0.58 (.33)</td>
<td>0.79 (.15)</td>
<td>36%</td>
</tr>
<tr>
<td>003</td>
<td>2.42 (1.44)</td>
<td>5.70 (2.36)</td>
<td>136%</td>
<td>0.50 (.18)</td>
<td>0.82 (.22)</td>
<td>65%</td>
</tr>
<tr>
<td>Set 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>002</td>
<td>1.75 (1.26)</td>
<td>3.19 (2.69)</td>
<td>82%</td>
<td>0.31 (.09)</td>
<td>0.41 (.24)</td>
<td>32%</td>
</tr>
<tr>
<td>005</td>
<td>0.30 (0.67)</td>
<td>0.92 (1.12)</td>
<td>207%</td>
<td>0.18 (.29)</td>
<td>0.15 (.17)</td>
<td>-16%</td>
</tr>
</tbody>
</table>
Running head: Motor Perspective Taking in Children with ASD

Motor and Verbal Perspective Taking in Children with Autism Spectrum Disorder:
Changes in Social Interaction with People and Tools

Breanna E. Studenka
Sandra L. Gillam
Daphne Hartzheim
Ronald B. Gillam

1Department of Health, Physical Education, & Recreation
breanna.studenka@usu.edu

2Department of Communicative Disorders and Deaf Education
sandi.gillam@usu.edu, ron.gillam@usu.edu, dhartz4@lsu.edu

Utah State University
Logan, UT 84322
USA

The corresponding author for this manuscript is Breanna E. Studenka.

3Daphne Hartzheim has since moved to the Department of Communication Sciences and Disorders, Louisiana State University, Baton Rouge, LA, 70803, USA.