**Loom History and Current Goals:**

To date, we have created and collected data for two versions of Loom (Loom v1 and Loom v2). There is a published conference paper and a journal article in review for data collected from Loom v1, and now we must decide what we are going to do with the data from Loom v2. Currently, the goal is to publish findings from the Loom v2 dataset, an autism journal. To do this, we must make a leap from the first paper’s finding and say something relevant to the field. The purpose of this document is to find a **potential** avenue of questioning that will drive the analysis and creation of this future publication.

From Loom v1, we were able to characterize how a virtual presence affects individual measures of gaze, movement, and arousal in autism. While interesting, due to the novel methodology, the characterization of difference alone does not really answer any questions about how social interaction is differently formulated and performed in autism, which is really the goal of using a dynamic social interaction game like Loom. We asserted that there are certain instances in movement, gaze behavior, and arousal where timing and degree of autonomic response are different in autistics compared to non-autistics and that most of these instances occur in a social cooperative scenario. It is encouraging that most of the individual findings for movement, gaze, and arousal have been produced before in some regard during smaller uni-measure experiments because most of those studies were not done in VR, so this work potentially adds credence to the paradigm as a viable substitute for some avenues of research. The gaze duration data for the view wall is particularly interesting because it shows a known *skill* that autistics have for static search and detail detection in the context of a highly dynamic situation. *(Baron-Cohen, 2017 - Editorial Perspective: Neurodiversity – a revolutionary concept for autism and psychiatry)*. From our current analysis, this was the only example of autistics being better than non-autistics as the other data for gaze and movement was found to be either statistically similar or autistic people were slower compared to controls. I would like to use the data set from Loom v2 to say something more specific and relevant to the topic of social interaction. Unfortunately, articulating how these autistic characterizations explain anything about their troubles with social interaction is difficult. Some of the reasons for this include direct challenges to our findings like:

1. This is a virtual environment and may not fully mimic a real social interaction.
2. The differences found between the groups are caused by something indirectly associated with social interaction, such as visual or game complexity, cognitive load ect…. *This covariate would have to be present only in the cooperative condition since that is where we see the majority of group differences.*

And more conceptual challenges regarding the nature of social interaction. Simply, it is difficult to describe specifically why autistic individuals are incapable of fluid social interaction when we do not really have a baseline for what comprehensive social interaction is.

**Finding a research question that incorporates multiple characteristics of autism and social interaction**:

Some autistic characteristics are easier to connect to their issues with social interaction than others, such as the use of gaze when making (or not making) eye contact or the lack of accuracy when identifying human emotions and social cues. Even so, these examples are difficult to contextualize more broadly about social interaction because of the aforementioned lack of specificity on the topic. It is plausible that these predominantly visual and cognitive characteristics of autism could be related to other autism-specific characteristics like their issues with motor control, which does not have such a direct link to social interaction. Combining these domains is an important step for the autism field because of the high likelihood that there is an underlying reason for both occurrences or at least some kind of a link. This reason, whatever it is, could be a vital piece of information for understanding the challenges that autistic people have with social interaction and developing practical clinical applications. Currently, Loom cannot do mechanistic research that would require neuroimaging techniques like EEG or fNIRS (possibly a future addition to the system), which would provide more tangible evidence for a connection to the domains of gaze movement and arousal, but it may not be necessary at this stage. Using Loom, we can investigate how autistic individuals are functionally producing gaze, movement and arousal responses in a social and non-social context. Our findings could be used as justification for future research attempting to find mechanistic relationships for these domains. Therefore, I believe that my task must now be to find a measure that answers the questions:

**Q1:** How do autistic individuals combine the use of gaze & movement (and possible arousal) differently than non-autistic people?

**Q2:** Do social situations/contexts impact this combination measure?

**A Measure Combining Movement, Gaze, and Arousal:**

To understand how individuals with autism are functionally combining multiple domains of action differently than non-autistics, we must find a task and measure that incorporates each of these domains.

Rather than having a standard start and stop to a task/trial, Loom allows the player to retain more agency over their decisions on how best to achieve a goal. In the pursuit of this goal, Loom facilitates several movements that players are required to do to complete the game’s objective. It is more useful to say that Loom allows players the freedom to choose the order of their actions, but the individual actions themselves are relatively consistent across players. There may be a question in the future about how the sequencing of actions changes between groups. The incorporation of tasks that are both positively and negatively affected by autism could be interesting to explore. The cross participant **intra-game tasks** that Loom currently facilitates are:

* Grabbing a cube on the Play Wall
* Placing a cube into a Drop Zone
* Checking the View Wall for information
* Turning from the Play Wall to the Build Wall

If we want to use some or all of these intra-game tasks as the structure for measurement, we must establish a precise timeline describing when each of them starts and stops. The peaks and valleys shown in the figure below could be a good place to start determining these breakpoints.



Additionally, we must at least consider previous research that has been done and incorporate it into the measure we are creating. This way, we can reference and expand upon previously established results. A good place to start is the *reach-to-grasp* literature, which is a highly researched movement in autism (and elsewhere) and is a developmental milestone for movement, so there is a direct link to clinical applications (which is good).

This paper: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1693116/pdf/12639336.pdf>

Is a foundational report on the topic of reach-to-grasp in autism. It outlines the kinematic differences of autism as well as a more complex topic, which is the differences in motor planning found in autistic individuals. The kinematic differences that lead to slower movement times are something that Loom 1 was able to show. Although reach-to-grasp can be described as two different movements, functionally, they are happening in parallel. While a person is reaching for an object, they are also preparing the aperture of their hand’s fingers to grasp it upon arrival. This parallel movement, which brings in a new term, “motor planning,” is now a full avenue of research in autism due to the differences shown here and in other places.

Motor Planning Paper: <https://www.sciencedirect.com/science/article/pii/S175094671>

Movement and gaze occurring in parallel for a singular goal could be a good place to start with the Loom v2 analysis.

This study: <https://onlinelibrary.wiley.com/doi/epdf/10.1002/aur.2478?saml_referrer>

Outlines a potential question about how autistic people are using their gaze and head movement in coordination differently than non-autistic people. Loom can expand upon this research by also including goal-oriented hand movements, which would be new to the field.

Using this potential measure, it is possible that we could answer Q1, but it doesn’t really fully address anything about social interaction and **Q2**. To do this, we need to have a better understanding of how social interaction and motor control are related. Motor abnormalities in autism (Fournier,Hass,Naik,Lodha,&Cauraugh,2010) have been found in many instances. However, there is a large amount of variability in these findings, and it is unclear as to why. Obstructed development or interventions could be the cause. Differences in neural physiology have also been consistently observed in autism, specifically in cerebral hemispheres, caudate nucleus, and cerebellum. Additionally, less integration among brain regions has also been found in autism. Decreased connectivity across the motor execution network relative to children with normal neurodevelopment could be one reason for the difference we see in motor control. These motor abnormalities still do not really get us that much closer to the issues found with social interaction. So, a more conceptual approach is needed.

**Literature concerning the combination of Movement and Social Interaction:**

# This paper: So close yet so far: Motor anomalies impacting on social functioning in autism spectrum disorder – Casatelli et al

<https://www.sciencedirect.com/science/article/pii/S014976341530258X?casa_token=cuEVAP19BoUAAAAA:nNyS5Ksjwd_sqVBNF6Bg2wBDDzkz6IUJ0JqqNn_F_n92wfyX38tffzihl_g-cKCcDD7v_LMM#bib0095>

Describes terms that could roughly outline a conceptual foundation for the different kinds of connections that exist between social interaction and movement. These terms **are “motor resonance” and “motor interference”**

**-Quote:** “Referring to ASD, the first one can impact the ability to directly understand (i.e., motor-based understanding) others’ behavior, whereas the second one may be considered a more general and pervasive motor marker of social anomalies.”

**Motor Resonance:** The type of evidence that is given in the paper for motor resonance is focused on the differences in motor planning and visual observation of movement that occur in autistic people. For example ([Cattaneo et al., 2007](https://www.sciencedirect.com/science/article/pii/S014976341530258X?casa_token=cuEVAP19BoUAAAAA:nNyS5Ksjwd_sqVBNF6Bg2wBDDzkz6IUJ0JqqNn_F_n92wfyX38tffzihl_g-cKCcDD7v_LMM#bib0115)) is a really cool experiment that uses EMG attached to the mouth muscle to record activation on a task that asks autistic and non-autistic kids to perform two actions. Action 1) Picking up food and putting it in the mouth and Action 2) Picking up food and putting it into a bin. The autistic group showed a late mouth activation occurring after the grabbing portion of the action in contrast to the non-autistic group, which did not. This implies that there is some kind of neurological issue affecting the functional activation of parallel movement and impacting motor planning. Interestingly, this study also contained a second “observational” condition where the participants watched someone else do both actions. The non-autistic group showed similar mouth activation while watching some perform the eating action, but the autistic group showed no activation while observing either action. Both of these results imply that the autistic group has difficulty visually encoding the goal of an action, which is more pronounced in a purely observational situations. The Casatelli paper also cites another paper:  [Boria et al., 2009](https://www.sciencedirect.com/science/article/pii/S014976341530258X?casa_token=cuEVAP19BoUAAAAA:nNyS5Ksjwd_sqVBNF6Bg2wBDDzkz6IUJ0JqqNn_F_n92wfyX38tffzihl_g-cKCcDD7v_LMM#bib0050) , which further highlights this inability to infer intention from motor cues specifically.

I think there is something that we can say about motor resonance using the head, hand, gaze combination measure.

**Motor Interference:**

Motor interference in autism is potentially a more direct link to the physical differences found in this population. It is also a phenomenon that is linked to gaze and the perception of movement, imitation, prediction and biological vs non-biological movement. These are all things that have been researched and found to be irregular in some way for people with autism.

**Kilner et al. (2003)**

In this study, they clearly outline how the observation of an incongruent movement negatively affects the production of movement when ONLY when observing human movement compared to observing robot movement. It suggests that we must try to understand how human movement is different from a robot’s in order to understand why this disruption in movement occurs. Some of the literature uses a minimum-jerk velocity profile as a divider for biological and non-biological movement. For example, use movement that varies in speed vs. continuous movement (Flash & Hogan, 1985).

**(Cook et al., 2014)**

In this study, they examine the movement interference effect from Kilner et al. (2003) in an autistic population. They show an effect of the autistic population having no interference effect when observing human and robot movements. The non-ASD controls did show an interference effect when looking at the humans.

“This result is in line with the finding of Pierno et al. (2008) that visuomotor priming was greater for control children relative to children with ASC following observation of human actions. However that visual motor priming was greater for ASD children when looking at a robot.”

**A Gap in the Literature: Movement and Social Interaction -> Autism Intervention**

From what I can tell, this is kind of where the literature ends for movement and its connections to social interaction. There is a body of literature that is new which is looking at using movement and exercise as intervention tools for autism and issues with social interaction. The preliminary studies have indicated very promising positive results (Reinders et al., 2019). However, there is a gap that connects the issues that we see with these interventions. It may be that it is difficult to design interventions based around research that is done in such a controlled and formalized manner. How can you design an intervention or suggest what types stimuli and movements to include if the research is only observing simple sinusoidal arm movements that are measured at specific moments in time. This is potentially to far away from the reality of how movement is used in social interaction.

How can we use Loom, which is a more dynamically real social interaction. And extract some kind of measure

**(Pineda et al., 2014)**

ASD neurofeedback training

[**https://www.annualreviews.org/doi/abs/10.1146/annurev-psych-010416-044046**](https://www.annualreviews.org/doi/abs/10.1146/annurev-psych-010416-044046)

A diagram of a autism spectrum disorder

Description automatically generated