Developing Methods for Understanding Social Behavior in a 3D Virtual Learning Environment

Matthew Schmidt*

James M. Laffey

Carla Schmidt

Xianhui Wang

Janine Stichter

* Corresponding author. Address: School of Information Science and Learning Technologies, University of Missouri. 118 London Hall, Columbia, MO 65211, United States. Tel.: +1 573 882 2374

E-mail addresses: schmidtma@missouri.edu (M. Schmidt), laffeyj@missouri.edu (J. Laffey), xw7t4@mail.missouri.edu (X. Wang), stichterj@missouri.edu (J. Stichter)

1 303 Townsend Hall, Columbia, MO 65211, United States. Tel.: +1 573 882 5399

2 444 Minnesota Avenue, Suite 300, Kansas City, KS 66101, United States. Tel.: +1 913 321-3143

3 118 London Hall, Columbia, MO 65211, United States. Tel.: +1 573 882 2374

4 303 Townsend Hall, Columbia, MO 65211 United States. Tel.: +1 573 884 9157
Keywords:

Three-dimensional virtual learning environments (3D VLE); Multi-user virtual learning environments (MUVEs); Autism Spectrum Disorders; All-views analysis; Social competency curriculum

ABSTRACT

This paper presents a case study of developing and implementing methods to capture, code and comprehend reciprocal social interactions in a three-dimensional virtual learning environment (3D VLE). The environment, iSocial, is being developed to help youth with autism spectrum disorders (ASD) develop social competencies. The approach to identifying, classifying and coding behavior in the 3D VLE uses an adaptation of reciprocal interaction coding methods traditionally used in single-subject research with individuals with ASD. These adaptations consider the unique characteristics of the 3D VLE technology and the nature and context of learning in this type of environment. A description of the coding methods employed is provided. Selected results are presented to illustrate how this methodology can offer detailed descriptions of learning and social interaction behavior in context. Such results demonstrate the potential of this approach for building new knowledge about how learning takes place and progresses in a 3D VLE and for making data-driven design decisions for improving the learning experience in the online social context.

1. Introduction

The purpose of this article is to describe our case of developing a methodology to study users' reciprocal interaction behavior in a three-dimensional virtual learning environment (3D VLE). Since 2008, we have been designing, developing and testing a 3D VLE called iSocial for
helping youth with autism spectrum disorders (ASD) acquire social competence. We chose to use 3D VLE technology because it has shown promise as a viable instructional technology both in general education (Dalgarno & Lee, 2010; Livingstone, Kemp & Edgar, 2008; McLellan, 2004) and special education (Cheng & Ye, 2010; Wallace, Parsons, Westbury, White, & Bailey, 2010; Cobb, 2002). In general education, systems such as Second Life and Active Worlds have made multi-user virtual environments (MUVEs) accessible to educators who wish to employ them. Applications built using MUVE technology such as Quest Atlantis (Barab, Gresalfi, Ingram-Noble, Jameson, Hickey et al., 2011; Barab, Sadler, Heiselt, Hickey, & Zuiker, 2007), River City (Ketelhut, Nelson, Clarke & Dede, 2010; Dede, Clarke, Ketelhut, Nelson, & Bowman, 2005) and EcoMUVE (Metcalf, Dede, Grotzer, & Kamarainen, 2010) are showing the potential of 3D VLEs designed as teaching and learning tools. While 3D VLE systems have a number of potentially effective learning benefits such as impacting motivation and engagement, these benefits and how to best leverage them are not yet well understood (Dalgarno & Lee, 2010). Great interest exists in using this medium for realizing potential learning benefits, but much of the literature in the field is based on anecdotal data and personal interpretations. Hence, many of the assumptions about potential learning benefits in 3D VLEs are not empirically supported.

In the field of autism spectrum disorders, 3D VLE systems are also gaining traction. ASD is a pervasive developmental disorder which, according to the American Psychiatric Association’s Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (1994), is manifested by impairments in social interaction, communication impairments and restricted, repetitive and stereotyped patterns of behavior, interests and activities. Of particular note are the difficulties individuals with autism spectrum disorder (ASD) experience with social interactions
which result in individuals with ASD having a higher likelihood to exhibit problematic social behavior and become socially withdrawn (Weiss & Harris, 2001). Failure to address social deficits can ultimately affect quality-of-life for these individuals (Myles & Simpson, 2002). Hence, identification of social competence deficits and targeted interventions designed to improve these deficits are critical for increased success and independence (Office of Special Education Programs, 2003). 3D VLEs are a promising technology and provide a number of potential benefits for social competence instruction such as predictable task repetition, the potential to adapt to the individual and control of input stimuli (Parsons & Mitchell, 2002). In addition, 3D VLEs offer the potential for role-playing in a realistic and compelling environment that may be intrinsically motivating, safe and completely controlled (Sansosti & Powell-Smith, 2008).

In a 2002 study (Leonard, Mitchell, & Parsons), seven participants with ASD were given the task to find a place to sit in a virtual café and a virtual bus. Participants (four male and three female, 14-16 years old with full-scale IQ scores between 65 and 110, mean verbal IQ of 81.9 and mean performance IQ of 87.1) were able to learn appropriate responses by using the VLE, and responded to feedback from the system and from individual coaching by the researchers. Findings indicate that social competence learning transferred between VLE and video media, but not between the café and bus contexts. The authors maintain these findings support VLE social competence training as a safe, calm alternative to in situ social competence training. Parsons, Leonard and Mitchell (2006) performed a case study on two individuals with ASD (both male, one 14 and the other 17 years old, with relative VIQ scores of 70 and 91 and FSIQ scores of 73 and 100) to investigate whether participants relate VE experiences to the real world and whether they enjoy using the VE and to provide rich examples of participant/facilitator interaction in the
VE. Virtual café and bus scenes were again used and the task was for participants to find a seat. Participants reported that they felt the VE had helped them and that they thought it was useful. They appeared to be motivated by the VE and stated that they enjoyed using it. When the participants made mistakes, they would laugh and joke about the mistakes, indicating that the social blunders they made may not have been interpreted as being as serious as in real life, nor as anxiety inducing.

While a handful of other studies exist supporting the use of social competence instruction in 3D VLEs for individuals with ASD (e.g., Cheng & Ye, 2010; Mitchell, Parsons & Leonard, 2007; Parsons, Mitchell & Leonard, 2005; Parsons, Mitchell & Leonard, 2004), knowledge in the field is limited and further research is needed (Cobb et al., 2002; Parsons et al., 2005). Little is known about how skills learned in the virtual environment might transfer to the real world. Further, the majority of studies dealing with social competence instruction in 3D VLEs focus on single user environments. These studies do not explore how multiple users might experience VE systems simultaneously. However, multi-user VEs might provide a number of benefits over single-user VEs. For instance, peer groups could discuss social competence collaboratively with a facilitator (Cobb et al., 2002) or social norms could be negotiated and developed between users (Parsons et al., 2005).

1.1 iSocial: A Multi-User 3D VLE for Social Competence Instruction

iSocial is a multi-user 3D VLE built using the Open Wonderland virtual worlds toolkit (http://openwonderland.org). The goal of iSocial is to develop a multi-user 3D VLE for helping youth with (ASD) acquire social competence. To this end, we have selected a successful face-to-face curriculum on social competence for adolescents with ASD that is typically administered in a clinic-like setting (Stichter, Herzog, Visovsky, Schmidt, et al., 2010) and have transformed the units and lessons to make them appropriate for delivery in a multi-user 3D VLE.
The transformed curriculum includes units on recognizing facial expressions, sharing ideas, turn taking, recognizing emotions and problem solving. Instruction takes place in social competence groups of four to six youth (aged 11 to 14), facilitated by an online guide who is a specialist in the curriculum and in working with youth with ASD.

In iSocial, youth come together online in the 3D VLE where they are represented by and act through avatars. They communicate and act using audio speech, text chat, gesture and movement in the virtual worlds. Various virtual worlds such as castles, pirate ships and restaurants provide a context for learning and practice activities. In these worlds, students are able to perform lesson activities which promote the discussion of social competence collaboratively with a facilitator and allow for the negotiation of social norms between users. The project has undergone extensive usability and usage testing and is curently being field tested in public schools. Testing iSocial with youth with ASD sensitized us to the challenges of facilitating and managing behavior so as to provide a coherent curriculum and social experience and to the complexity of studying and understanding behavior in a 3D VLE. We became aware that we needed a way to identify, codify and examine behavior in our multi-user 3D VLE that would allow us to better understand how students behave socially in the system, how their behavior in the virtual worlds is mediated by the system and how different lesson activities impact their social behavior.

In the following sections, we describe our case of developing a methodology to study users' reciprocal interaction behavior in iSocial. While the methods and tools we are developing are somewhat customized to youth with ASD developing social competence, we believe they are of interest to developers, researchers and practitioners who want to move beyond measures of perceptions, behaviors and outcomes outside the virtual experience and be able to analyze the
implications of design decisions on student behavior within the 3D VLE in order to make connections between behavior and learning outcomes. To this end, we present a methodology which looks specifically at users' reciprocal interactions in the 3D VLE, is sensitive to the tools which mediate these interactions and also to the learning and activity contexts in which these interactions are couched.

2. Conceptual Framework

Individuals with ASD typically desire to be social but do not have the requisite social competencies to do so successfully, with their inability to identify and act on nonverbal social cues and social prompts tending to result in displays of socially unacceptable behavior (Myles & Simpson, 2002). The iSocial project and underlying social competency curriculum are designed to help remediate such social defects and foster social interaction. The curricular approach to teaching and learning depends on social interaction and conversation among students and with the online guide. For this reason, it was necessary for us to develop a system of analysis capable of measuring and representing social interaction. We identified extant methods for analyzing conversations and their corresponding coding schemes such as computer-mediated negotiated interaction (Smith, 2003) and conversation analysis (Sacks, Schegloff, & Jefferson, 1974). In addition, we investigated prior work that seemed similar to ours such as the coding methods used in the virtual peers project (Arie, Tartaro, & Cassell, 2008) and discourse analysis methods used in the Quest Atlantis project (Barab et al., 2007). These initial investigations helped us to narrow our focus to the framework of reciprocal social interaction (cf. Patterson & Reid, 1970).

Based on Bandura’s social cognitive theory, reciprocal interactions impact human development through a two-way relationship between the person, the environment and their behavior (Merrell & Gimpel, 1998). Successful reciprocal interactions occur when a learner makes and receives approximately the same amount of peer initiations and responses
and are contingent on the context and planned opportunities to provide them (Roeyers, 1996). As a result, these reciprocal interactions assist in the acquisition of new skills and overall social competence (McConnell et al., 1991). In studies that attempt to elicit social interaction among individuals with ASD, researchers often look at initiations, responses and continuations as a primary outcome measure (Morrison, Kamps, Garcia, & Parker, 2001; Thiemann & Goldstein, 2001).

Most studies looking at reciprocal interaction with individuals with ASD utilize some form of single-subject design, a methodological design type in which the participant or participants act as the control, as opposed to using a control group. The goal of single-subject research is to demonstrate a functional relationship between an intervention and a target behavior. Single-subject research demonstrates experimental control in the same vein as randomized control group designs (Horner, Carr, Halle, McGee, Odom, et al., 2005) and is recognized by the U. S. Department of Education as an effective means to evaluate research questions appropriate to the methodology in applied and clinical fields (Kratochwill, Hitchcock, Horner, Levin, Odom, et al., 2010). While we have elected to use a reciprocal interaction framework and to borrow from single-subject design research methodology, it is important to clarify that our approach differs from a traditional single-subject design in that we are not looking for an experimental effect. Instead, our methodology considers what reciprocal interaction behaviors participants demonstrate when using iSocial and how those behaviors might relate to the unique characteristics of the 3D VLE experience and technology features. As a result, we needed not only to measure reciprocal interaction behaviors in the iSocial 3D VLE, but also to identify any associations specific to the medium and to highlight technological activities that might impact the behaviors. Therefore, we adapted the traditional approach of
looking at conversational initiations, resposes and continuations to consider the technology characteristics which might impact participants’ interactions, as well as the virtual world contexts in which the reciprocal interactions occur. Our methods section provides an overview of our process for building this methodology.

3. Methods

A field-test of one unit of the iSocial curriculum was undertaken in the Fall of 2008 at a large autism research and treatment center in the Midwest which yielded our data set. The curricular unit focused on turn-taking in basic conversation, in which students learn the cues and processes of conversational turn-taking. Lesson activities consisted of the youth having opportunities 1) to learn about turn-taking in the 3D VLE through lessons provided by the online guide, 2) to try out and practice the skills in both structured and more naturalistic contexts and 3) to interact in social ways with peers and the online guide. The unit consisted of four lessons which were built in a virtual lighthouse. In each lesson, areas were provided in the lighthouse for students to perform lesson activities, including such activities as introduction, modeling, structured practice activities and more naturalistic practice activities. In the physical world, participants sat at a computer with a facilitator and used microphone-equipped headsets to communicate with members in the virtual world. In the virtual world, participants interacted with each other and the online guide as avatars with the ability to speak, gesture, move and act on the environment.

3.1. Participants

Four youth undertook the instruction with assistance by an online guide and facilitators who physically sat with them. These four youth met a set of pre-defined qualifications for enrollment in the social competency curriculum: they 1) were between 11-14 years old, 2) had a medical diagnosis of autism determined by the Autism Diagnostic Interview Revised (ADI-R)
and/or the Autism Diagnostic Observation Schedule (ADOS) (Lord, Rutter, DiLavore, & Risi, 2002) were verbal/capable of speech and 4) had an intelligence quotient within one standard deviation of the mean for the typical range (e.g., a score of 85-115).

Participants were enrolled in a social competency curriculum using the same curriculum as iSocial. They and their parents were asked if they were interested in taking part in iSocial testing, and permission forms that were approved by the campus’ institutional review board were completed by each participant and his parents before taking part in the testing.

3.2. Data Collection

Video recordings of participants using the 3D VLE system were collected both virtually and in the physical world during each of the four sessions. iShowU (http://www.shinywhitebox.com/) screen recording software was used to capture participants’ interaction in the virtual world. Video cameras were set up in the participants’ physical spaces to capture their interaction with the computer and with their physical facilitators. Videos were created for each participant in each of the four lessons in the turn-taking unit.

3.3. Coding Process

ELAN Linguistic Annotator (http://www.lat-mpi.eu/tools/elan/), an open source software tool that allows the creation, editing and searching of annotations in video and audio data, was used for coding. ELAN was configured for simultaneous viewing and coding of multiple synchronized videos and transcripts (Figure 1). This made possible a comprehensive and simultaneous view of all users both at the computer and within the virtual world, a method we term "all-views analysis" (Goggins, Schmidt, Guajardo, & Moore, 2011).
3.5. Inter-observer Agreement

Measures of inter-observer agreement (IOA) were taken for reciprocal interaction coding. Agreement was assessed using the point-by-point agreement method as per Kazdin (1982) and was obtained for 25% of the video data, as per Cooper and colleagues (2007). IOA for all coding levels was between 80% and 90% for all sessions. Agreement was determined by both observers agreeing that a behavior had occurred, whereas if one marked the behavior as occurring and the other did not or marked it as a different behavior, it was marked as a disagreement. If agreement was less than 85%, coders would review the coding scheme and clarify their understanding of codes and then re-code the data independently. Given the significant calibration effort on the part of the coding team to reach agreement scores that were greater than 85%, we are confident in our agreement metric; however, we also recognize that more robust methods could provide even more confidence, such as Cohen's Kappa, which would account for coincidental agreement. Indeed, we will use the Kappa statistic for assessing agreement in future studies.

3.6. Coding Scheme Description and History
The reciprocal interaction coding scheme was developed iteratively by the iSocial team. A review of reciprocal interaction coding schemes (for example, McEvoy, Nordquist, Twardosz, et al., 1988; McKenney, Asmus, Conroy, et al., 2005) served as the basis for development of a provisional reciprocal interaction coding scheme. We realized that these coding schemes were not able to represent unique elements of the 3D VLE which impact interaction, such as technological tools and the activity contexts within the virtual space. To better characterize the unique nature of reciprocal interaction within the 3D VLE, the coding team revised the provisional coding scheme to capture reciprocal interaction on three levels: 1) the context for reciprocal interaction (context level), 2) the reciprocal interaction itself (the interaction model level) and 3) the means of interaction (the interaction mode level). These levels are described in Table 1.

Table 1
Level definitions for the reciprocal interaction coding scheme

<table>
<thead>
<tr>
<th>Coding level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction model level</td>
<td>Describes reciprocal interactions as a series of initiations, responses and continuations. Allows researchers to see at a glance, for example, if a verbalization (mode of interaction) made while discussing a presentation (context) is a conversational initiation, response or continuation, and whether the interaction is appropriate or inappropriate to the social context.</td>
</tr>
<tr>
<td>Interaction mode level</td>
<td>Provides a detailed view of the means (e.g., verbalization, text message, avatar gesture) of reciprocal interaction. Allows researcher to see at a glance, for example, that for a given duration of time learners’ mode of interaction consisted primarily of mouse clicks, with some verbalizations and text messages.</td>
</tr>
<tr>
<td>Context level</td>
<td>Describes where in the virtual world interactions are occurring, the activity in which learners are engaged and what technological supports (if any) form the specific context for those interactions. Allows researcher to see at a glance, for example, that at a specific time in a lesson, learners were engaged in playing a browser game in the foyer area of the lighthouse virtual environment.</td>
</tr>
</tbody>
</table>
3.6.1. Interaction Model Level

The interaction model considers initiation, response and continuation behaviors and represents them as socially appropriate or inappropriate. Definitions for the interaction model codes are found in Table 2. These codes allow us to examine not only whether interaction occurred, but also whether that interaction was socially appropriate.

**Table 2**
Interaction model of the reciprocal interaction coding scheme

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td>Participant emits a verbal, textual or gestural behavior to indicate communication. Coded as an initiation only if it is not preceded by another interaction from the peer(s) or instructor(s) to whom the initiation was directed within three seconds.</td>
</tr>
<tr>
<td>Response</td>
<td>Acknowledgement of interaction that is executed within three seconds by the peer(s), instructor or physical facilitator from whom the response was solicited by the initiator and is on-topic.</td>
</tr>
<tr>
<td>Continuation</td>
<td>Designates the beginning of sustained interaction that is on-topic and happens within three seconds of the preceding response.</td>
</tr>
<tr>
<td>Non-response</td>
<td>A response or continuation to an interaction is expected but the participant fails to acknowledge the interaction in any way within three seconds.</td>
</tr>
<tr>
<td>Interruption</td>
<td>A verbal articulation that occurs when someone else is speaking or has the floor to speak, regardless of relevance to the current conversation/lesson.</td>
</tr>
<tr>
<td>Overlap</td>
<td>An inadvertent or unintentional interruption in which one person is speaking and another begins speaking in a way that is not inappropriate.</td>
</tr>
<tr>
<td>Inappropriate initiation, Inappropriate response, Inappropriate continuation</td>
<td>An initiation, response or continuation which: is off-topic; indicates that the participant is not paying attention; uses an inappropriate tone; is rude or insensitive; is socially unacceptable; or does not follow directions.</td>
</tr>
</tbody>
</table>
3.6.2. Interaction Mode Level

The convention of capturing reciprocal interaction behaviors using initiation, response and continuation was developed primarily for face-to-face interactions and did not provide a means to account for the range of interaction possibilities provided by 3D VLE technology. For example, avatar interaction can take the form of gestures, such as nodding yes or no, but these gestures are initiated with a mouse click and not simply by kinesthetic body movement.

Participants are also able to move about the virtual space and take turns making selections or interacting with objects. Consequently, we needed a set of codes to provide a more detailed characterization of the technological means of interaction within the 3D VLE, i.e., verbalization (via headset), text message (via keyboard entry), avatar gesture (via mouse click), etc. Interaction mode codes and definitions are provided in Table 3.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>Used to identify participant verbalizations.</td>
</tr>
<tr>
<td>Gesture</td>
<td>Used to identify participant use of available avatar-based gestures.</td>
</tr>
<tr>
<td>Action</td>
<td>Used to identify mouse clicks on elements within the virtual world, such as games.</td>
</tr>
<tr>
<td>Movement</td>
<td>Used to identify avatar movement within the virtual space.</td>
</tr>
<tr>
<td>Text</td>
<td>Used to identify participant use of text chat.</td>
</tr>
<tr>
<td>Other</td>
<td>Interaction mode behaviors that do not correspond with interaction model behaviors. For example, movement that is not a response or unarticulated verbal expression, such as one participant who often was humming during the sessions.</td>
</tr>
</tbody>
</table>

3.6.3. Context
The context level of coding considers three different contexts: a) where the participants are interacting in the virtual world (the primary context); what curricular task they are engaged in (the lesson context); and what technological tools are enabling the activity they are undertaking within the curricular task (the affordance context). These three levels are necessary since 1) participants’ interactions in the virtual world are completely mediated by technological tools, 2) activities vary across lessons, from highly structured to less structured practice activities, and take place in different areas of the virtual world, and 3) participants move their avatars through the virtual world as lessons progress. The three levels of context codes represent the virtual world as a set of stages for reciprocal interaction, characterized as a complex ecology of user behavior and interaction, curricular activities, virtual scenes and technological tools. This ecological perspective of learning in iSocial presents a view of context as being mediated, dynamic and elastic.

4. Application

Using the all-views technique described previously, video data were prepared for coding by importing them into the ELAN linguistic annotator and creating coding projects for each session and each group. Using the coding manual discussed in the previous section, coding of the data was split into three phases. Data were coded at the interaction mode level during the first phase, the context level during the second phase and the interaction model during the third phase. This three phase coding process was amenable to the ELAN software’s workflow and was adopted because coders were able to code with higher agreement when focusing on only one phase of coding at a time. The coded data were imported to Microsoft Excel and graphed. These graphs provide an aggregate view of reciprocal interactions in context with reciprocal interaction rates plotted on the Y-axis, corresponding contexts on the X-axis and percentages of interaction
mode codes displayed as stacked 100% columns within each lesson context. These graphs represent participants’ coded reciprocal interaction-in-context (Figure 2). Graphs were created using this method for each participant and for each session.

![Graph](image-url)

**Fig. 2.** Sample graph depicting results of reciprocal interaction coding for one participant in one session.

Because these graphs contained such a large magnitude of data, they were both difficult to read and interpret and were therefore used as masters for creating derivative graphs to highlight specific portions of the data. Derivative graphs were created by collapsing the three levels of context into a single context (see Figure 3). Due to space constraints, contexts are represented in the graphs as abbreviations. Definitions for these abbreviations are provided in Table 4.
5. Findings

In applying this methodology to data from our pilot study for the iSocial research project we found that we were able to represent participant behavior at a very detailed level and analyze these behavioral data at a variety of levels of granularity. This helped us to understand how well the youth are meeting and progressing on expectations for certain forms of social behavior, as
well as pinpoint the contexts and activities that best promote the types of behavior that the social skills curriculum teaches, both at an individual level and in comparison to one another.

For example, Figures 4 and 5 show the full set and range of appropriate behavior for participants FN and UB during lesson two of the turn-taking unit. Based on the objective of the examiner, several forms of representation could be employed. These two figures use the percentage of observed behavior to total opportunities for that behavior to represent interaction model behavior and mode behavior, but another representation could use frequency numbers. One way to gain insights about the youth behavior and performance in the curriculum is to look at how different contexts drew different behaviors. For example examining Figure 4 shows that some activities drew singular forms of behavior such as the practice activities (PA) and finishing activities (FA) eliciting only verbal behavior while other activities such as starting activities (SA) elicited multiple forms of behavior (talk, movement and gestures). Also, comparisons of youth provide insight into how response and behavior in the system may vary across participants. For example, examining initiations shows for FN that initiating interaction rose and fell from activity to activity but often reached 40% of the total opportunity for behaviors in a session, whereas for UB the level of initiation remained mostly lower than this across the session.
Fig. 4. Complete aggregate of reciprocal interaction model across contexts for participant FN in Lesson 2.
Across all participants and all lessons, we found that the dominant interaction model behavior in iSocial was response. The mean percentage of response across participants and across lessons was 55.65%. Initiation was the least dominant interaction model behavior, with a mean percentage across participants and lessons of 20.99%. For some participants (F.N., U.B.), initiations were on average higher, and for others (Q.C., U.Z.), continuations were on average higher. Across participants and lessons, the most dominant form of inappropriate behavior was interruption, with a mean of 9.33% of all interaction model codes. Breakdowns of average percentages of interaction model behaviors are provided in Table 5.

### Table 5
Percentile means of initiations, responses, continuations and interruptions among participants across all four lessons of the turn-taking unit.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Initiation</th>
<th>Response</th>
<th>Continuation</th>
<th>Interruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.N.</td>
<td>26.19%</td>
<td>51.03%</td>
<td>21.83%</td>
<td>4.58%</td>
</tr>
<tr>
<td>U.B.</td>
<td>29.09%</td>
<td>45.25%</td>
<td>17.38%</td>
<td>21.08%</td>
</tr>
<tr>
<td>Q.C.</td>
<td>8.82%</td>
<td>72.01%</td>
<td>19.17%</td>
<td>2.76%</td>
</tr>
<tr>
<td>U.Z.</td>
<td>19.85%</td>
<td>54.31%</td>
<td>25.84%</td>
<td>8.92%</td>
</tr>
</tbody>
</table>

The dominant mode of interaction was verbalization. The mean percentage of verbalization across participants and across lessons was 51.48%, followed by movement at 7.62%, gesture 5.95% and action at 3.64%. Text was the least dominant interaction mode, with a mean percentage across participants and lessons of 0.66%. Breakdowns of average percentages of interaction mode codes are provided in Table 6.

### Table 6
Mean percentages of interaction mode codes for all four lessons of the turn-taking unit.
<table>
<thead>
<tr>
<th>Participant</th>
<th>Verbalization</th>
<th>Gesture</th>
<th>Action</th>
<th>Movement</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>F.N.</td>
<td>49.41%</td>
<td>3.40%</td>
<td>5.97%</td>
<td>3.91%</td>
<td>0.99%</td>
</tr>
<tr>
<td>U.B.</td>
<td>48.13%</td>
<td>5.23%</td>
<td>6.20%</td>
<td>6.73%</td>
<td>0.46%</td>
</tr>
<tr>
<td>Q.C.</td>
<td>47.52%</td>
<td>5.35%</td>
<td>1.77%</td>
<td>14.62%</td>
<td>0.00%</td>
</tr>
<tr>
<td>U.Z.</td>
<td>60.86%</td>
<td>9.81%</td>
<td>0.62%</td>
<td>5.22%</td>
<td>1.17%</td>
</tr>
</tbody>
</table>

To summarize, the dominant appropriate reciprocal interaction behavior was response, the dominant inappropriate reciprocal interaction behavior was interruption and the dominant mode of interaction was verbalization. Referring the reader again to Figures 4 and 5, we are able to see these trends represented visually in the graphs. For both participant FN and UB, response is clearly represented as the dominant reciprocal interaction across nearly all contexts. Similarly, verbalization dominates all other interaction mode behaviors across all contexts.

6. Discussion and Conclusions

Our key objective for establishing the methods presented in this report has been the thorough description and representation of reciprocal social interaction behaviors in iSocial. This approach seems to be a good fit for researching small group interaction in collaborative 3D VLEs. Not only does this approach take into account prior methods of coding and analyzing reciprocal interaction in the real world, it also accounts for characteristics and affordances unique to the 3D VLE. Our report describes an approach to collecting and representing discrete behaviors of individuals within activity and learning contexts. These representations offer perspectives on studying single subjects in learning technology contexts that fit with the formative nature of testing an evolving system and address the social nature of the learning context. This can be helpful in analyzing implementation processes in the 3D VLE and iterating theory and design (Wang & Hannafin, 2005), which can in turn help to systematically improve
practices and features to best support the teaching and learning processes, (Reeves, 2006).
Researchers who desire to establish a gestalt representation of the ecology of small group
learning and interaction in 3D VLEs are likely to benefit from similar methods.

Representations such as Figures 4 and 5 and Tables 6 and 7 illustrate the potential of our
methodology to examine reciprocal interaction behaviors in context and how conclusions
gleaned from such representations can be used to improve design. Information from these types
of representations could be used to answer such questions as whether performance matches
expectations for competent behavior, or whether skills develop as youth progress through
lessons, which could in turn provide guidance for decisions about whether activities or activity
spaces could be improved to enhance interaction or performance. For example, Figure 4 shows
participant FN’s rates of appropriate response to total opportunities averaged around 45% across
lesson activities, and rates of appropriate continuations were quite variable, averaging around
25%. Under ideal circumstances we would hope that the youth would improve performance as
they moved from early activities to later activities. However, the data do not indicate a trajectory
of improved performance, which could reflect some differences across the activities or needs for
improvement within the design of the activities. These rates do, however, show us that youth can
participate by responding and continuing interactions in these contexts, although one might hope
for higher rates of performance. While the data as represented in Figures 4 and 5 do not provide
a sufficient answer for decisions of what to improve or whether the system is satisfactorily
meeting learning objectives, they do indicate that improvements can be made. In the case of
these lesson activities, further design is called for so that data from usage of the next versions can
be compared to these figures for a test of progress.
A limitation of our approach, however, is that the representations presented in this report do not represent the sequence of participant interactions through a lesson. However, the sequence of behaviors can be very informative. For instance, an interaction with several continuations back and forth between the youth might indicate a desirable turn taking incident. In turn we could look at the context to see what activities or design features were associated with that form of interaction. Other sequences of interest might be an initiation without any response, a series of initiations or a series of initiation and response patterns that do not result in continuations. Recognizing the value of such data representations, we have begun to investigate more rigorous means for accounting for activities in context and how the behavior of multiple actors might elicit reciprocal behaviors.

As the iSocial project moves forward we note several ways that we and other researchers can advance the basic methods we have described in this report. First, we can envision extensions of the coding system or new systems to address lessons with different objectives. For example a lesson that includes problem solving may want to include codes for when the youth propose or provide a solution (Hou, Chang, & Sung, 2008) or a lesson that focuses on knowledge construction may want to include codes for sharing and negotiation (Gunawardena, Lowe, & Anderson, 1997). Second, we are investigating and developing ways of having the computer provide some forms of learning analytics that can either stand alone as behavioral representations or be used by the manual coder in making decisions about codes (Hasler, 2010). Third, we could identify high value or high interest sequences of behavior, such as a response followed by three appropriate continuations or an initiation without any response, and then search the data set for all occurrences. Fourth, we are looking into more advanced ways to represent user behavior, such as using transitional state diagrams to investigate interaction patterns (Jeong, 2005) and
social network analysis (deLaat, Lally & Lipponen, 2007). As a final next step we can look for associations between levels of behaviors and other measures. Do youth with certain characteristics participate in ways that are different from other youth? Is a high level of reciprocal interaction associated with other measures of positive outcomes? Do environments with more structure or less structure lead to different levels of reciprocal interaction? Can we design special features into the 3D environment to invite or constrain certain forms of behavior, and do they work?

As researchers, designers, developers and implementers of 3D VLE there is much to learn and discover about 3D VLE and its potential as an educational resource. We believe that a focus and advancement for how we study the behaviors and processes undertaken in these systems is critical. The methods described in this report attempt to address the complexity of learning when mediated through a 3D VLE and using avatars as representative of participants and when the learning behavior is dynamic and social with an online guide and with other youth. The tools for capturing the data, the protocols and tools for coding the data and the representations we use to comprehend the data have proven helpful in our investigation as well as pointing the way to improvements in methods and advancement in our understanding of learning in 3D VLE.
Acknowledgements

This research was made possible by the generous contributions of the Thompson Center for Autism and Neurodevelopmental Disorders and a grant from our university research board.

References


