# Measuring the meaning conveyed by a glance or a gesture in a Computer Supported Collaborative Learning Environment

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## Abstract

This paper investigates the role of gaze and gesture when subjects were collaboratively solving physics problems with a computer. The results indicate that gesturing has an important role to play when subjects are discussing collisions since they use their hands to denote speed and force of an impact. More surprisingly, however, gesturing was also associated with problem solving success when subjects were supporting one another with very positive feedback and also when disagreements arose between them. Mutual gesturing also impacted upon the planning process of the investigation. However, more mutual gesturing and gazing occurred with female pairs rather than male and mixed gender dyads. Problem solving success also correlated with gaze which again was associated with cognitive planning and the provision of positive and negative feedback among partners. To conclude our main finding is that differences in non-verbal communication strategies effect not only the strategies that progress the collaborative process but more importantly also those that influence the understanding of the problem space. These results suggest the quality of video linkage will play an important role in collaborative solving for distance learners.

**Keywords** - Problem solving, gaze and gesture, gender, collisions.

## Introduction

Social interaction in groups to progress cognitive understanding has become an important issue both for developmental psychology and educational research (Perret-Clermont et al., 1991, Linn & Burbules, 1993 and Barfurth 1995). A large number of studies have commented upon how learning has resulted from a group's collective efforts to understand new information and there has been an examination of the type of talk (Whitelock 1993, Mercer 1994, Wegerif 1996) which accompanies computer supported collaborative learning activities. Studies with children have also found that peer presence facilitates problem solving (Joiner et al, 1991) and that gender too has a mediating effect (Loveridge et al, 1993). However, there has been little principled investigation into the role of the non-verbal interactions which accompany and support such cognitive skills as planning and problem solving within a CSCL setting. Gender composition has also received little consideration within this context.

It has been argued by Isroff (1996) that motivational issues should be considered in CSCL environments and hence the roles that gaze and gesture play in motivating and sustaining collaborative interactions requires attention. This paper reports the results of a study which focuses upon the role of gaze and gesture when adults are collaboratively solving physics problems with a computer. We were particularly interested in investigating the following issues:

1. What types of inter subject events promote gaze and gesture?

2. Do these events influence the joint problem solving process?

3. What mediating effect does gender play in this process?

These questions are not as trivial as they seem, since there is controversy about the role of eye contact in establishing successful collaboration. Kraut et al (1990) suggest that the visual channel is necessary to initiate a conversation in informal communications while Taylor et al (1993) propose that eye contact is important especially in the high level planning stages of collaborative problem solving. Sellen's (1992) work challenges the importance of eye contact, however, the tasks she used were different to Taylor's problem solving exercises. Also Sellen adopted a different type of analysis from Taylor which was context free.

We are not only concerned with understanding the role of non-verbal interactions with respect to problem solving success but also how these findings impinge upon the quality of video linkage that should be used to support distance learning students following a science foundation course.

## Methodology

### Subjects

The subjects involved in this study consisted of a selection of adults who all had experienced some form of science education with 89% specifically taught Physics. This was an important selection criterion otherwise the subjects would not have been able to solve the problems set. We chose adults with a mean age of 39.9 years (s.d 11.8) because they make up our own University's student population. We allowed subjects to work in friendship groups because past experience has shown subjects do not collaborate and work independently if not paired with an appropriate partner. Other evidence suggests that friendship pairs perform best, (Azimita and Montgomery 1993), although this is an issue which needs further exploration in the distance learning context.

### The experimental procedure

Subjects' understanding of collisions was pretested followed by an experimental session where they worked together in pairs. The first part of the questionnaire was designed to find out what the subjects had learnt about the nature of elastic collisions. They were asked to make predictions about the post collision motion of two ice pucks in five different scenarios and to elaborate upon their understanding of kinetic energy and momentum. The second part of the questionnaire (see Whitelock and Scanlon 1996) measured the number of effective factors which could have impinged upon the learning experience.

All the students were given time at the beginning of the session to explore the simulation and to try out any scenarios that interested them. Once the subjects felt they understood the domain and had exploited the simulation as an information resource they were aced to solve three different problems. These problems required the subjects not to predict the result of a collision but to state the original conditions for a given outcome. The subjects worked in pairs within their gender groups and all sessions were video recorded.

### PuckLand - the computer simulation

The PuckLand simulation v 2.6 was written in Hypercard for use with the Apple Macintosh computer. It used a direct manipulation approach, which allowed students to investigate a series of collisions between two ice pucks. It consisted of a pair of pinball-style flippers on either side of the screen with which subjects could flick pucks. The amount of force with which the flippers hit the pucks could be varied, as could the mass of the pucks. The ice pucks, ranging from 1 to 100 units of mass, could be dragged into position ready to be struck by the flippers.

The initial velocity of the collision was controlled by directly manipulating the angle of the flipper from 90 to 180 degrees in the vertical plane. Before the "Go" button could be activated subjects had to **qualitatively predict** the speed and direction of the ice pucks after collision. When the "Go" button was pressed the pucks moved towards each other on the screen and were animated with a speed proportional to that set by the initial angle of impact executed by the flipper. The program also highlighted the icons with the correct answers after the experiment was run. This is a very specific approach to using science simulations. We have found in a number of studies that pairs perform best when they adopt a predict look and explain modus operandi ( see Scanlon et al 1993) and this piece of software was designed to specifically encourage these type of learning interactions.

## Results

### Event Categories

| SUBJECT GROUP | n |
|---|---|
| Side by side Male | 14 |
| Side by side Female | 16 |
| Side by side Mixed | 18 |

**Table 1** : Number of subjects who worked in the side by side condition when using the PuckLand program.

In order to understand the types of activities and discourse which prompted the subjects to gaze and gesture to one another; all utterances and non-verbal interactions were transcribed and coded. In this analysis it is recognised that talk proceeds through a series of turns but that the most basic social identities relevant to turn are those of the Speaker and Hearer (see Goodwin 1981). This analysis focuses on how the turn is constituted through the mutual interaction of Speaker and Hearer. The gaze of the Speaker was marked above the utterance and that of the gaze recipient (Hearer) was marked below it. A pencil line indicated which pair member was gazing toward the other. The absence of the line shows that a partner was not gazing toward the other. With respect to gesture a convention was constructed which followed a similar format for gaze. A green continuous line indicated that a subject was directly pointing at the computer screen. A green dotted line was a gesture used to explain the movement of the ice pucks and finally a pencil line with arrows donating its beginning and end represented any movement of the hands. In this way both Speaker and Hearer's non-verbal communication appears together with the "talk".

Each gaze and gesture marked on the transcript was coded with respect to the type of talk that accompanied it, (inter rater reliability 79%). After all the occurrences were accounted for the discussions which prompted gaze and gesture fell into seven major categories. These included talk about the Computer Program, the Motion of Ice Pucks, Strategies to progress the Investigation, Strategies to progress Understanding of the problem space, talk which provided Feedback to Partner i.e. grounding incidents and finally utterances that provided both positive and negative emotional support.

### Events that prompt gaze and gesture

The types of interactions that were coded in these seven major categories, are documented in Table 2 below. This is an exhaustive list which accounted for all the data and incidences of each were not found for every gaze condition. This meant that Speaker, Hearer and Mutual gazing were prompted by incidences reported in all seven event categories. The only exception with respect to gesture was with Mutual gesture and no incidences were recorded for this condition in the progressing understanding condition. It was only the Speaker or Hearer who employed hand movements when asking questions, explaining, predicting and elucidating understanding.

### Gaze and 'on task' problem solving success

The subjects were given three problems to solve when they were working with the simulation and we have investigated whether problem solving success correlates with the amount of non-verbal interaction that is associated with discussions centred around the seven categories described in Table 2, (Spearman's Rank correlation co-efficient was used to test the correlation between these two variables). There were a number of event categories that were all associated with Speaker, Hearer and Mutual gaze that significantly correlate with problem solving success. These included interactions related to progressing the investigation ($Z = 3$ $P<0.004$ Speaker and Hearer, $Z = 4$ $P<0.001$ Mutual), feedback to partner ($Z = 2$ $P<0.024$) and changes associated with emotions negative ($Z= 3$

| MAIN CATEGORY | SUB CATEGORY | MAIN CATEGORY | SUB CATEGORY |
|---|---|---|---|
| MOTION OF ICE PUCKS | Mass, Velocity, Formulae, Relationship variables, Comparison to other systems | FEEDBACK TO PARTNER | Commenting on result, What does partner think?, Answering question, Showing partner what to do, Don't know |
| COMPUTER PROGRAM | Interface problems | EMOTIONS - POSITIVE | Confirming, Agreeing, Surprise, Fascinated |
| PROGRESSING THE INVESTIGATION | What to do next, Already done that, Lets try it, Tell Partner something, Give instructions, Talk about questionnaire | EMOTIONS - NEGATIVE | Disagreement, Confused, Something wrong, Difficult, Hesitate, Admit wrong |
| STRATEGIES TO PROGRESS UNDERSTANDING | Explaining, Asking question, Predicting, Elucidating understanding | | |

**Table 2 :** Details of Event Categories

P<0.06). Here we see that planning activities were associated with eye gaze. However, we have labelled this category not as planning, but as strategies employed to progress the investigation.

With respect to Hearer and Mutual gaze, the three key areas of interaction which were common to both concern discussions about firstly the pucks (Z = 2 P<0.017 Hearer gaze, Z = 2 P<0.045 Mutual gaze), secondly around dialogue which progressed understanding (Z = 3 P<0.01 Hearer gaze, Z = 2 P<0.01 Mutual gaze) and thirdly, exchanges classified as positive emotional support which were only associated with problem solving success for Mutual gaze (Z = 3 P<0.004).

### Gesture and on task problem solving success

Gesturing was always prompted through discussion of the movement of the pucks. It was practically impossible for the partners to exchange ideas about the collisions without moving their hands and arms in some way. (Z = 3 P<0.001 Speaker gesture, Z = 1 P<0.001 Hearer gesture and Z = 4 P<0.0001 Mutual gesture). Another type of movement of the hands occurred for all conditions when the pairs were providing each other with Mutual support (Z = 2 P<0.02 Speaker gesture, Z = 4 P<0.0001 Hearer gesture and Z = 4 P<0.001 Mutual gesture). When the partners were approaching difficult issues, such as disagreement or confusion, admitting something was wrong or one partner did not understand what the other one was doing, again there was hand movement. These types of actions have been described in our event category system as a negative emotional response and occurred for the Speaker gesture (Z = 3 P<0.006), Hearer gesture (Z = 3 P<0.007) and Mutual gesture (Z = 3 P<0.001). Mutual gesturing also correlated with problem solving success with respect to progressing the investigation (Z = 4 P<0.0001). This was also the case of Hearer gesture associated with strategies to progress the investigation (Z = 4 P<0.0001).

### Gender differences with respect to gaze and gesture

There were significant differences with respect to gender and gaze. In fact it was the Speaker in the male pairs who looked at his partner more when talking about the motion of the ice pucks than the other gender groups (F = 4 P<0.05; one way anova of gender vs category of talk with respect to Speaker gaze). This meant in effect that the speaker looked at the hearer while the hearer was looking at the computer screen. It was, however, the females who used a mutual gazing strategy when talking about the ice pucks (F = 4 P<0.05). With respect to Progressing Understanding; it was the female Speakers who gazed significantly more in this condition than the other gender groups (F = 1 P<0.05). They also gazed more than the other groups when discussing the workings of the computer program (F = 3 P<0.0l).

The significant differences occurred with the mixed gender pairs who gazed significantly less than the single sex pairs when Progressing the Investigation (F = 3 P<0.05) and also providing positive emotional support (F = 1 P<0.01) to one another. In the mixed pairs, it was the Speaker who did most of the gesturing since there was less Hearer gesturing (F = 4 P<0.05) and Mutual gesturing (F = 2 P<0.02) in this gender condition. With all gender pairings the Speaker controlled most of the problem space and there was no significant difference by gender for Speaker gesture with respect to the seven event categories. Where differences were found it was the male Hearers who gestured more about the motion of the ice pucks than the mixed pairs (F = 1 P<0.015) and Mutual gesturing was more common with the female pairs. This type of mutual interaction was more significant when the females (F = 1 P<0.05) were planning (F = 2 P<0.001) providing feedback to their partner and also engaged in discussions about the ice pucks (F = 2 P<0.02).

## Conclusions

The types of inter subject events that prompt eye gazing and gesture fall into seven main groupings. Two of which were primarily concerned with the subject domain and the workings of the computer program. These have been described as "Motion of Ice Pucks" and the "Computer Program" in our event category system. We have found that gesture associated with talk about the motion of the ice pucks has a significant correlation with problem solving success. It was very difficult for the subjects to discuss collisions without using their hands to denote the speed and force of an impact. Gesturing played a big part in the decisions that were made about what sorts of experiments to perform with the simulation, i.e. how and when to change the salient variables of mass and velocity. Quantifications were thereforeindicated through speech and gesture.

With gazing and domain interactions there was not a significant association with Speaker gaze and problem solving success when discussing the motion of the ice pucks. It was only when the Hearer looked at the listener who was talking about the motion of the pucks that a significant relationship occurred. The problem space was mainly controlled by the Speaker and it was the Speaker's actions rather than gaze which were more important here than when the subject domain per se was discussed. This finding could well be an atypical one since the topic of elastic collisions involves notions which are perhaps more easily described via gestures. Therefore this type of analysis needs to be applied to another subject discipline which does not focus around the subject of dynamics.

Another important category that prompted gaze and gesture was that of cognitive planning which in our framework is referred to as "Progressing the Investigation". How did gesture and gaze with respect to this event category influence the problem solving process? The data from this study suggested that a number of incidents of eye gazing during the planning phase correlated with problem solving success. This data supports Taylor et al's (1993) observation that eye contact was important in the planning stage of an empirical investigation. In addition Mutual gesturing and strategies employed to progress the investigation correlated significantly with problem solving achievement and hence the non-verbal interactions of gaze and gesture were acting in different ways with respect to problem solving and planning activities.

The other event categories concerned with strategies to "progress understanding" were associated with mutual gaze related incidents or those of the Hearer only. Mutual gesturing events were also associated with this category but the non-verbal interactions were not as frequent and significant with respect to joint problem success as the other event categories mentioned above. What is perhaps more surprising is the role of gesture when partners were offering both negative feedback and positive support to one another. Gazing was associated with these types of interactions and there were no significant differences with respect to gender for these latter event categories.

There were, however, significant differences with respect to gender and gaze. Male Speakers gazed more when talking about the motion of the pucks. Female Speakers differed in that they looked at their partners more when trying to progress mutual understanding of the problem space. It was the mixed gender pairs who gazed less than the two other gender groups when providing emotional support or progressing the investigation.

Our categories of talk which precipitated gaze and gesture were in agreement with many accounts of discourse and language use (e.g. Grosz and Sidner 1986 and Litman and Allen 1987) which assume that as we talk we tend to look for evidence that we have been misunderstood and then attempt to repair the problem. This process was called "grounding". Other forms of grounding were seeking positive understanding such as acknowledgements which take the form of "yeah", "yes" and "mmm" (Schegloff 1981) and gestures such as head nodding (Goodwin 1981). There was also the "next turn" phenomenon which indicates comprehension has taken place and the third and most basic form of positive evidence was continued attention. Mutual gazing was an indicator of this latter phenomenon and was prompted by discussions about how to progress understanding of the problem space and talk which offered positive emotional support.

To conclude, our main finding suggests that gesture and gaze play different roles in constructing the problem space and continuing the collaboration process between the dyads. Understanding how this interplay also effects problem solving when subjects are linked with a video conferencing system will be part of our future work. This will allow us to make recommendations about the quality of visual links that are required to sustain collaborative learning at a distance.

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