Chapter 1

Introduction & Background Work

1.1 Need for Social Interactions:

People participate in social interactions every day with friends, family, co-workers and strangers. A strong set of social skills is critical in life—for example, they help us make new friends or make good first impressions at job interviews. Sociologists believe that social interactions are the underpinnings of over modern society and are essential for social development and acceptance of an individual within our society [1]. Social interactions refer to all forms of interpersonal communication between the participants that they deem necessary to initiate and maintain interactions. This could be bilateral (between two individuals) or group interactions (between multiple people). Irrespective, all the participants are engaged in continuous exchange of social information through their behaviors, mannerisms, gaze, posture, proxemics and kinesis [2]. Years of research in human communication, behavioral psychology, and social psychology has culminated in our understanding of social interactions to have two important functions in our everyday lives.

1.1.1 Psychological Support:

Recent studies by Segrin et al. [3] have shown that poor social skills are antecedents to psychosocial problems including depression, loneliness, social anxiety, etc. The authors conducted a battery of tests on college students to determine the effect of stress on the students when they live at away from home. Figure 1 shows Depression and Loneliness plotted against stress levels of undergraduate students. Depression was measured using the Beck Depression Inventory [4], while Loneliness was measured on the UCLA Loneliness Scale (version 3) [5] as an index into the students experience of loneliness. For both of these tests, the participating students were categorized into high, medium and low social skilled groups based on the Social Skills Inventory [6] (a battery of tests administered to determine the socialization ability of an individual).

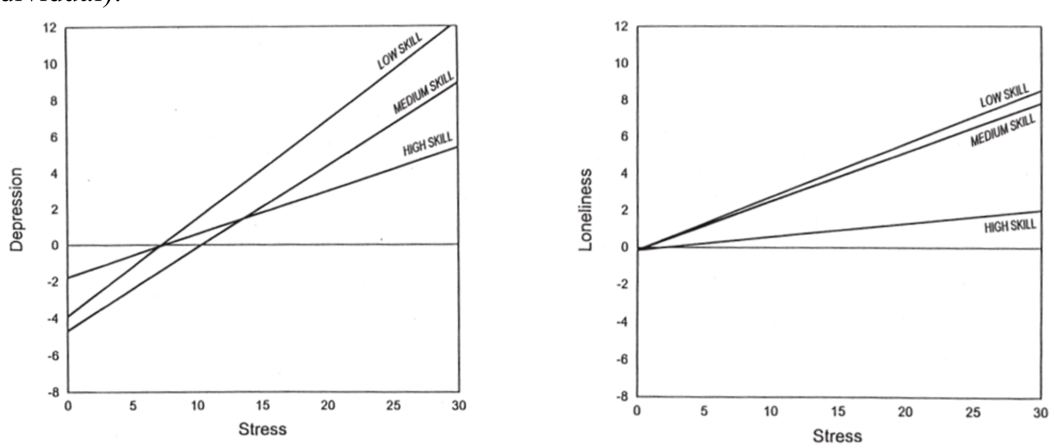


Figure 1: Depression and Loneliness of students plotted against stress levels in high, medium and low social skilled undergraduate students. (Please see text for the scales used for the measurement.)

One can immediately identify a positive correlation between stress and an increased experience of psychosocial problems in all the students, but the ones that rank higher on social skills show higher resistance to stress and in turn higher resistance to mental breakdown. Students assessed with mild or lesser social skills were highly vulnerable to social issues as the stress increased.
Similar results were found in [7] where the authors conclude that people with high competence in communication are known to display immense capability towards adapting their social behavior based on others in their surroundings. Such competence has been acknowledged to reinforce social skills thereby creating a reinforcement feedback that allows these individuals to be successful in their social endeavors [8] and in turn successful in their life. In a tangential study, though Magnusson [9] was not looking for social interaction needs in people, found that social interaction is an important dimension in the cognitive organization of human behaviors. When college students were assessed individually, and as a group, to determine how they classified everyday activities into different situations, Magnusson discovered 5 dimensions (Principle Dimensions). These included two dimensions based on whether the students perceived a situation as being positive (*positivity*) or negative (*negativity*) influence on their behavior, two dimensions based on whether the situations were *active* or *passive,* and finally, the fifth dimension was based on *social interaction* with others. His study emphasizes how social interactions are perceived by individuals as an important scale for judgments on their activity of daily living.

1.1.2 Social Intelligence:

Studies in Cognitive Psychology support the hypothesis that social interactions play a vital role in the overall development of intelligence in humans, especially, in the development of Social Intelligence (or Interpersonal Intelligence [10]) and Emotional Intelligence [11]. Social and Emotional intelligence are vital components in an individual understanding the importance of other people and things in their surroundings. Without active social interactions, a large part of the learning component is lost.
Social Intelligence (SI) can be defined as the competence in initiating and maintaining group interactions and behaviors. First defined by Edward Thorndike, Social Intelligence is “the ability to understand and manage men and women, boys and girls, to act wisely in human relations” [12]. Karl Albrecht [13] argues that Social Intelligence is the basis for five important aspects for an individual to mingle into his/her society, including, 1) Situational awareness, 2) Sense of Presence, 3) Authenticity (or Individuality), 4) Clarity (of action), and 5) Empathy.
Emotional Intelligence (EI) describes the ability, capacity, and skill to identify, assess and manage the emotions of one’s self, others and of groups of individuals. Many models have been proposed in the past to explain EI, such as Ability based models [14], Mixed models [15] and Trait based models [16] and all these models point towards the fact that reduction in social interactions can reduce the overall understanding of an individual of their place in the society. Recently, EI metric scales have been used to diagnose autism spectrum disorders, including autism and Asperger syndrome, semantic pragmatic disorder or SPD, schizophrenia, and Attention-deficit hyperactivity disorder (ADHD). These measurements have

shown a direct correlation of one's ability to increase their overall emotional involvement within the society by increasing their social interactions.

While most SI and EI models have provided theoretical understandings of the importance of social interactions, primate researcher, Humphrey [17], has demonstrated the real-world effect of social interactions to cultural transmission of knowledge and the development of intelligence. His studies with rhesus monkey have emphasized the positive influence of social interactions on the development of general intelligence. For example, Helen (a rhesus monkey) had her visual cortex surgically removed and studies were conducted on her recovery of spatial vision. Over four years, isolated within the laboratory, Helen hardly recovered any of her spatial knowledge. However, when she was taken out of the laboratory into the real world and allowed to interact with objects and other monkeys, she regained three dimensional spatial vision within a few weeks. Humphrey argues that the interactions with other monkeys were key to Helen's learning of interactions (both with objects and other monkeys).

From a neuro-physiological perspective, advanced functional brain imaging is enabling researchers to study the workings of human brain under various functional conditions and they are confirming the role of social intelligence to an important aspect of human learning. Brothers [18] has worked extensively on the neuro-physiological patterns in primate brains that are associated with social behavior. Her work has established the presence of dedicated brain regions involved only in *social cognition* (Social cognition is the processing of information that culminates in the accurate perception of dispositions and intentions of other people). She has proposed a network of neural regions that comprise the social brain and she argues that a malfunction of the any component of the social brain results in reduced social cognition. Her work has been recently bolstered by [19], where the authors study autistics and controls under functional Magnetic Resonance Imaging (fMRI). The subjects watched another person's eye expressions, and guessed what that person was thinking or feeling. The fMRI images confirmed Brothers observations of STG and amygdala activations during social cognition, and showed that people with autism display a cognitive disability in the amygdala which prevents them from making appropriate mental inferences of other people's emotions or facial expressions. Authors conclude that a social brain does exist, and that teaching children and adults social skills could offer a means of increasing activations in the social brain. This conclusion is supported by the behavioral research in autism that employs social interaction training and language skill training in children to ameliorate the social deficits characteristic of autism spectrum disorders (ASD).

1.1.3 Summary:

In summary, social interactions are vital to the workings of our society. Humans learn through their social interactions and these interactions form the basis of our psychological and mental stability. Any disruption to the social interactions of an individual will definitely affect their ability to assimilate into the society. Years of research and observation has shown that sensory, perceptual and cognitive disabilities are a leading cause of such disruption in social interactions. Once there is a disability set in, the loop of social learning through social interactions is permanently damaged thereby causing a chain of related problems.

1.2 Non-verbal Cues – Essential component of Social Interactions:

Social interactions and social skills primarily correspond to the two main channels of communication [20]

- *Verbal communication:* Explicit communication through the use of words in the form of speech or transcript.
- *Non-verbal communication:* Implicit communication cues that use prosody, body kinesis, facial movements and spatial location to communicate information that may be unique or overlapping with verbal information.

From a communication point of view, nearly 64% of all information communication happens through non-verbal cues [21]. Out of this large chunk, 48% of the communication, is through visual encoding of face and body kinesis and posture, while the rest is encoded in the prosody (intonation, pitch, pace and loudness of voice). Inability or difficulty to access any part of this non-verbal cues, seriously affects the overall understanding of the social scene and reduces the involvement of an individual in the social interactions.

1.2.1 Encoding of Non-verbal Cues*:*

From the perspective of encoding information into non-verbal cues, speech, voice, face and body form the primary channels of communication in any social interaction. Speech forms the primary channel for verbal communication, while prosody (intonation, pace and loudness of one's voice), face, and body (posture, gesture and mannerisms) form the medium for nonverbal communication. Unlike speech, which is mostly under the conscious control of the user, the non-verbal communication channels are engaged from a subconscious level. Though people can increase their control on these channels through training, innately, individuals demonstrate certain inability to control their non-verbal cues. This inability to control non-verbal channels is referred to as the leakiness [22] and humans (evolutionarily) have learnt to pick up these leaked signals during social interactions. For example, people can read very subtle body mannerisms very easily to determine the mental state of their interaction partner. Eye Gaze is a classic example of such subtle cues where interaction partners can detect interest, focus, involvement and role play, to name a few. On this leakiness scale, it has been found that the voice is the leakiest of all channels, implying that emotions of individuals are revealed first in their voice before any of the other channels are engaged. The voice is followed by body, face and finally the verbal channel, speech. The leakiness is plotted on the abscissa of Figure 2 with the ordinate showing the amount of information encoded in the other three non-verbal communication channels. It can be seen that the face communicates the most amount of non-verbal cues, while the prosody (voice) is the first channel to leak emotional information.

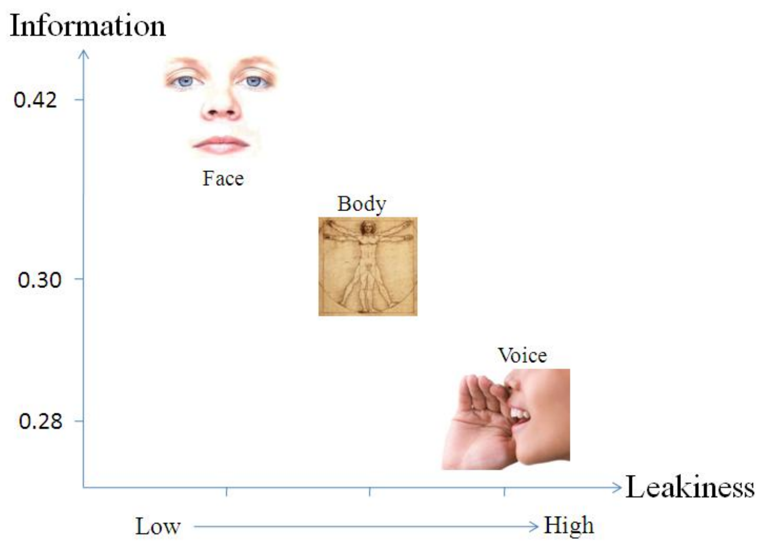


Figure 2: Plot of communicative information encoded in the three important non-verbal channels of encoding. Speech forms the verbal channel. Face, body and voice form the non-verbal communication channels.

1.2.2 Decoding of Non-verbal Cues:

From the perspective of decoding non-verbal communication cues, the human input channels can be analyzed under,

a) ***The auditory channel*** (includes conscious, verbal speech and unconscious, nonverbal voice),

b) ***The visual channel*** (includes nonverbal face and body mannerisms and gestures, which are distributed fuzzily between the conscious and unconscious mediums),

c) The combined Audiovisual channel (includes simultaneous verbal and nonverbal communication mediums), and

d) The touch (includes the nonverbal conscious haptic sensory perceptions).

Figure 3 shows the encoding and decoding components of non-verbal communication (scales for the verbal, non-verbal, audio and visual components are arranged based on the numbers). It can be seen that most part of interpersonal communication is encoded into the non-verbal channels with the visual media conveying the most amount of information.

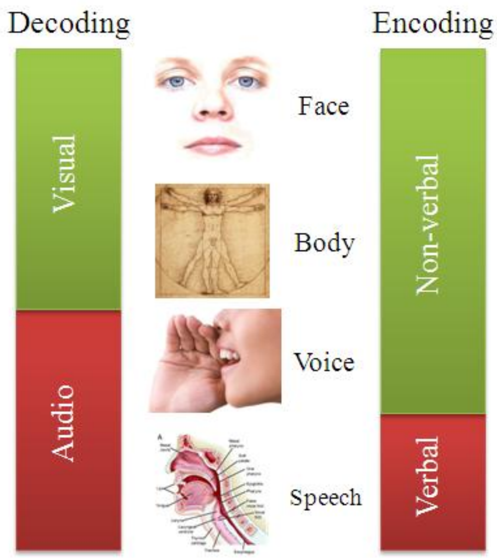


Figure 3: Shows the encoding and decoding aspects of interpersonal communication. From an encoding perspective, humans use verbal and non-verbal cues to communicate while from a decoding perspective, face and body encoded data is received visually and verbal speech and non-verbal prosody are received through audio.

1.2.3 Summary:

Non-verbal communication cues form the basis for human interpersonal interaction with vital information encoded into two important channels of vision and hearing. *A large component of these cues are visual in nature thereby requiring individuals to decode non-verbal visual cues before getting involved meaningfully in any social interactions.*

1.3 Components of Non-verbal Communication:

Non-verbal communications are inherently complex in nature. In order to understand the nature of these cues, psychologists have been studying these cues under three subdivisions based on what affects individual's non-verbal cueing [2]. These subdivisions include,

a) The communication environment,
b) The physical characteristics of the communicators, and
c) The behaviors of the communicators.

1.3.1 The Communication Environment:

The communication environment or surroundings where the interactions are taking place make a huge difference of how humans respond or react [23] [24]. For example, lengthy periods of extreme heat [25] are known to increase discomfort, irritability, reduced work output and unfavorable evaluations of other. Along with the interaction partners, the environment either reinforces or depreciates the emotional experience of an individual. For example, wide open spaces and natural environments are known to be conducive for psychological stability [26]. Though the environmental factors just perceptual, they impose a lot of control on how humans react towards them. Some of the important environmental factors that affect interpersonal communication and non-verbal cueing are shown in the table below. These are some of the well identified factors towards which psychologists and sociologists are working towards.

The Communication Environment	
Familiarity of the environment	[27][28]
Colors in the environment	[29][30]
Other people in the environment	See next two subsections.
Architectural Designs	[31]
Objects in the environment	[32]
Sounds	[33][34]
Lighting	[35]
Temperature	[25]

1.3.2 The Physical Characteristics of the communicators:

The physical appearance of a person is very important aspect of non-verbal cueing. People draw impressions of their communication partner as soon as they see them. The human body acts like means for communicating important sociological parameters like status, interest, dominance etc. Researchers have found cultural and global preferences in overall body image and any deviations from the norm affects interactions between people. For example, facial babyishness [36] has been found affect judgment of facial attractiveness, honesty, warmth and sincerity. Any deviation from the babyishness has been correlated to immediate reduction in the judgment of these traits. A similar such example is the clothing that people wear. It has been found that first impressions are positive if the interviewer and interviewee are clothed similarly [37]. The table below shows the important aspects of a person's physical appearance that affects the interpersonal interaction. Various psychological studies have been conducted towards understanding the model of human perception of character. Very little is known on the reasons for some of the human norms, but it is an active area of research that is being explored rigorously, especially, in the context of group behaviors and personal mannerisms with work environments [38].

Physical Characteristics that affect interpersonal communication	
The human facial attractiveness	[36][39][40]
body shape	[41][42]
height of a person	[43]
self image	[44]
body color	[45]
body smell	[46][47][48]
body hair	[49]
clothing	[37][50]
personality	[51][52]
body decoration or artifacts	[53]

1.3.3 Behavior of the Communicator:

The last of the three units of non-verbal communication is the behavior of the communicators. While the term behavior is used loosely in defining this unit, this encompasses both static posture and dynamic movements demonstrated by communicators. Of the three units of non-verbal communication, the behavior forms the most important aspect. Most part of the emotional information encoded by humans is delivered through the behavior of individuals during social interactions. Gestures, Posture, Touch and Voice form the basic subdivisions in behavioral non-verbal cueing. While the entire human body is important for the communication of these cues, the face and eyes play a major role.

1.3.3.1 Gesture:

Gestures are dynamic movement of face and limbs displayed during interpersonal communication. Together, they convey a lot of information that is sometimes redundant (with speech) while other times deliver emotional information about the enactor. Most often gestures are classified based on their occurrence with speech. Accordingly, there are

a) Speech-independent gestures, or emblems (like shrug, thumbs up, victory sign etc), that are mostly visual in nature and convey the user's response to the situation [54][55].
b) Speech-related gestures, or illustrators (pointing to a thing, drawing a shape while describing etc) [56].
c) Punctuation gestures, that emphasize, organize and accent important segments of a communication, like pounding the hand, raising a fist in the air etc.

1.3.3.2 Posture:

Posture refers to the temporary limb and body positions assumed by individuals during interpersonal interactions. Posture is a very effective medium for communicating some of the important non-verbal cues like leadership, dominance [57], submissiveness and social hierarchy [58]. For example, people who show a tendency of dominance tend to extend their limbs out while sitting thereby displaying an overall larger body size. Similarly, submissiveness seems to be correlated to reducing the overall body size by keeps the limbs together.

Both gestures and postures are influenced heavily by the cultural background of the individual and also varied with the geographical location [59]. Though the cultural influence if true with other non-verbal and verbal cues, the perceived difference is the highest in gestures and posture displayed by individuals.

1.3.3.3 Touch:

Social touch has been a very important aspect of non-verbal communication in humans. Developmental biologists believe that the first set of sensory responses in a human fetus is touch [60]. From a social context this sensory channel is very well used in conveying important interpersonal cues such as interest, intimacy, warmth, confidence, leadership and sympathy [61]. Touch is a powerful means of unconscious interaction and it is believed that people who are very good in their social skills rely upon touch a lot [62].

Historically, the sense of touch (Haptics Communication [63]) has been studied by psychologists in the perspective of understanding the human sensory system, but recently, haptics has grown out into the technology front providing human machine interfaces that augment or replace visual and auditory interfaces [64].

1.3.3.4 Face:

The face is the primary channel for non-verbal communication. Humans are efficient in conveying and receiving plethora of information through subtle movements of their face and head. This focus on the face develops from a very young age and it has been shown that by 2 months, infants are adept in understanding facial gestures and mannerisms [65]. The human face has very fine muscular control allowing it to perform complex patterns that are common to humans, while at the same time being vastly individual [66]. The facial appearance of an individual is due to their genetic makeup, transient moods that stimulate the facial muscles and due to chronically held expressions that seem to set in and become permanent. Human visual system has developed the ability to read these subtleties on people's faces and interpret all the three aspects of the face - genetic makeup (person's identity through face recognition), transient mood (facial expression and emotion recognition), and permanent expression on the face (default neutral face of individuals). While the aspects of permanent facial appearance are important in the recognition of the individual, from a non-verbal communication perspective, the primary function of the face is directed towards communicating emotions and expressions.

The understanding of the human facial expression space was immensely increased by the work of Ekman, Frisen [67] and Izard [68] in the late 1970s. They independently measured precise facial movement patterns and correlated these individual movements with facial expressions on the human face. While Izard developed these patterns on infants, the Facial Action Coding System (FACS) developed by Ekman and Frisen has become the de facto standard for measuring facial expressions and emotions. FACS allow expression and emotion researchers to encode facial movements into accurate contraction and relaxation of facial muscles. Based on these facial actions, Ekman and Frisen discovered the global occurrence of seven basic judged emotions. As psychologists have started to master the FACS system of analyzing facial actions, human computer interaction specialists have started to use the same FACS encodings for building better interfaces that can determine human affect and respond accordingly.

1.3.3.4.1 Facial Action Coding System (FACS):

FACS defines all possible facial feature movements into Action Units (AU) which represent movement of facial features (like lips, eye brow, chin etc). The AUs are the net effect of facial muscle contraction and relaxation, though they are not directly related to the muscles. Table below shows the different AUs that form the basis of FACS based facial coding with the appropriate number and the associated facial feature movement.

- 1 Inner Brow Raiser
- 2 Outer Brow Raiser
- 4 Brow Lowerer
- 5 Upper Lid Raiser
- 6 Cheek Raiser
- 7 Lid Tightener
- 9 Nose Wrinkler
- 10 Upper Lip Raiser
- 11 Nasolabial Deepener
- 12 Lip Corner Puller
- 13 Cheek Puffer
- 14 Dimpler

- 15 Lip Corner Depressor
- 16 Lower Lip Depressor
- 17 Chin Raiser
- 18 Lip Puckerer
- 19 Tongue Out
- 20 Lip stretcher
- 21 Neck Tightener
- 22 Lip Funneler
- 23 Lip Tightener
- 24 Lip Pressor
- 25 Lips part
- 26 Jaw Drop
- 27 Mouth Stretch
- 28 Lip Suck
- 29 Jaw Thrust
- 30 Jaw Sideways
- 31 Jaw Clencher
- 32 Lip Bite
- 33 Cheek Blow
- 34 Cheek Puff
- 35 Cheek Suck
- 36 Tongue Bulge
- 37 Lip Wipe
- 38 Nostril Dilator
- 39 Nostril Compressor
- 41 Lid Droop
- 42 Slit
- 43 Eyes Closed
- 44 Squint
- 45 Blink
- 46 Wink

1.3.3.5 Eye:

Like the human face, eyes are very important for the control of non-verbal communication. This involvement of human eyes comes from the functions that gaze and mutual gaze play in everyday human interpersonal communication [69]. People use their gaze to convey subtle information that enables smooth verbal interaction which eventually leads to information exchange [70]. From a research perspective, the function of gaze has been classified into four important functional categories [71][2]. These include

1.3.3.5.1 Regulating the flow of communication.

One of the most important functions of gaze is the regulation of verbal communication in bilateral and group communications. People use gaze to shift focus, bring the attention of a group of people to one thing, turn taking in group conversations [72] and eliciting response from communication partners [73].

1.3.3.5.2 Monitoring feedback.

Gaze provides a means for individuals to get feedback during conversations and communications. Feedback is a very important tool while people converse. Humans study the eyes of the listener to cognitively inject or eliminate more verbal information into the conversation [74].

1.3.3.5.3 Reflective of cognitive activity.

Both listeners and speakers tend not to gaze at others when they are processing complex ideas or tasks. Studies have shown that people can answer better when they close their eyes and are allowed to process their thoughts [75]. Thus, cognitive processing is displayed very elegantly by monitoring eye gaze patterns.

1.3.3.5.4 Expressing emotions.

Along with the facial muscular movements, the eyes play a vital role in the expression of emotions. In fact, in human computer interaction research, it has been found that relying on the eyes and the eyelids alone can provide more accurate delivery of affect information when compared to the entire face [76]. Verbal communication tends to move the lips and mouth quickly and randomly that can make image and video processing of expressions very tough. Some of the more recent *spontaneous expression* recognition research is focusing on the eyes for this very reason.

1.3.4 Summary:

In summary, non-verbal cue communication specifically depends on the environment, physical appearance of the communicators and the behaviors of the communicators. While all three components play important roles in determining the net effect on the interpersonal communication, the *most important aspect of the non-verbal communications are focused on the face, eye and body mannerisms of the communicators*. Further, most part of these communications are visual in nature and require the communicator's visual attention to determine the subtle cues. *Unfortunately, this implies that the visual senses of all the communicators need to be fully engaged in this process and people who are blind or visually impaired face problem during such scenarios.*

1.4 Visual Impairment - a hindrance to Social Interaction:

As explained above, most part of the non-verbal encoding happens through visual media. While some parts of these cues are delivered along with speech, most part of the nonverbal communication is inaccessible to someone with visual impairment or blindness. This disconnect from the visual stimulations deprive the individuals of vital communicative cues that enrich the experience of social interactions. People who are blind cannot independently access this visual information, putting them at a disadvantage in daily social encounters. For example, during a group conversation it is common for a question to be directed to an individual without using his or her name—instead, the gaze of the questioner indicates to whom the question is directed. In such situations, people who are blind find it difficult to know when to speak because they cannot determine the direction of the questioner's gaze. Consequently, individuals who are blind might be slow to respond or talk out of turn, possibly interrupting the conversation. As another example, consider that people who are blind cannot use visual cues to determine when their conversation partners change positions (e.g., pacing the floor or moving to a more comfortable chair). In this scenario, an individual who is blind might inadvertently create a socially awkward situation by speaking in the wrong direction.

To compound these problems, sighted individuals are often unaware of their non-verbal cues and often do not (or cannot) make appropriate adjustments when communicating with people who are blind. Also, people who are blind often do not feel comfortable asking others to interpret non-verbal information during social encounters because they do not want to burden friends and family. The combination of all these factors can lead people who are blind to become socially isolated [3], which is a major concern given the importance of social interaction. While people who are blind and visually impaired face a difficulty in social interactions, research in rehabilitation training for these populations recommends that the social involvement for these individuals have to substantially increase in order to enable their acceptance of the society.

National Center for Health Statistics reported in 2007 that the estimated number of visually impaired and blind people totals up to 21.2 million in the United States alone[1]. Global numbers are daunting. In 2002 more than 161 million people were visually impaired, of whom 124 million people had low vision and 37 million were blind[2]. WHO reports that more than 82% of the populations who are blind or visually impaired are of age 50 or older. With the life expectancy going up in most developing countries, the percentage of general population entering into some sort of visual impairment is going to increase in the coming years.

Recently, Jindal-Snape [77][78][79] carried out extensive research in understanding social skill development in the blind and visually impaired. She has studied individual children (who are blind) from India where the socio-economic conditions do not provide for trained professionals to work with children with disabilities. Her seminal work in understanding social needs of children who are blind have revealed two important aspects of visual impairment that restricts seamless social interactions. These include.

1.4.1 Inability to learn social skills due to the lack of visual feedback:

Jindal-Snape observed that significant others in the environment often fail to give feedback, and even when they do, it is not meaningful or understandable to an individual who is visually impaired—for example, nodding one's head in reply to a question or gesturing. Lack of meaningful feedback could make it difficult for visually impaired persons to comprehend a conversation [78] [80]and, at times, may stop conversing. Similar studies carried out by Celeste [81] indicated that social intervention by parents and teachers are very important in the formative years of a child with visual impairment. Developing on the work by [82], which emphasizes that short-term feedbacks are never effective, Celeste insists that professionals must identify strategies related to social skills that work, provide consistent support and follow children longitudinally to ensure effective development of social skill set.

People who are sighted do not necessarily have the training to work with individuals who are blind or visually impaired. Thus, unconsciously they tend to neglect people who are blind. For example, sighted people use gaze as a primary means of keeping attention with people they communicate with. While conversing with a person who is blind or visually impaired, sighted individuals expect the same gaze feedback. The lack of such a feedback distracts the sighted individuals to turn their attention to or assume disinterest from the visually impaired individual. Research indicates that blind individuals with the ability to accommodate social requirements of their sighted counterparts have exhibited immense personal and professional growth.

1.4.2 Development of stereotypic body mannerisms, especially body rocking, as they don't get a reinforcement visual feedback on their mannerisms:

Due to the lack of visual feedback, people who are blind and visually impaired do not have access to learn mannerisms from their social counterparts. Especially, people who are impaired at a very young age find it very difficult to learn appropriate social actions and mannerisms. A

[1] J.R. Pleis and M. Lethbridge-Çejku, *Summary health statistics for U.S. adults: National Health Interview Survey, 2006*, National Center for Health Statistics, Vital Health Stat 10 (235), 2007.

[2] World Health Organization: *Magnitude and causes of visual impairment*, Fact Sheet N°282 November 2004.

stereotypic body mannerism is one such scenario where positive reinforcement through visual stimulation would have prevented the individual from developing acute non-social conditions.

For over three decades, researchers in behavioral psychology have been publishing case studies on individuals who exhibit stereotypic body rocking. Most of these studies have targeted at reducing or controlling stereotypic body rocking. The methodologies used by these researchers, though varying in nature, can be broadly classified into two important categories.

1.4.2.1 Intervention:

Intervention relates to any form of feedback provided to an individual at the moment of exhibiting stereotype behaviors. Researchers have attempted to reduce body rocking by providing audio and/or tactual intervention whenever an individual started to rock. They have tried aversive punishment as well as less restrictive positive feedback in such situations. Felps and Devlin [83] issued an annoying tone in the ears of the subject while [84] used a recording of stone scratching on blackboard as the feedback tone whenever the individual started rocking. Both reported that the subjects responded well to the intervention. In contrast, [85], [86] and [87] have used verbal praise, physical guidance, verbal reprimands, and brief time-outs as intervention tools. Most of these researches have shown that intervention has worked in reducing and controlling body rocking without the use of aversive techniques. Aversive or not, these techniques validate a claim that it is possible to control or reduce body rocking (or any other stereotypic body mannerism) through feedback.

1.4.2.2 Self Monitoring:

In contrast to intervention, self-monitoring does not stop at intervening into the activities of the individual. It attempts to teach these individuals subtle cognitive skills to replace the current mannerism with more socially acceptable behavior, exercise, or medications. McAdam and O`Cleirigh [88] identifies that self monitoring is a very effective way of reducing the body rock behavior. They introduce the case of a congenitally blind individual who is trained (with constant monitoring and positive feedback) to count the number of body rocks he goes through. Researchers noticed that the individual slowly waned off body rocking as he came to recognize and count his body's oscillatory movements. The research concludes that a well designed self monitoring program could benefit in reducing stereotypic body rocking. Shabani, Wilder and Flood [89] presents the case of a 12 year old child who was diagnosed with attention deficit hyperactivity disorder (ADHD) having an excessive body rocking and hand flapping stereotypy. The authors introduce an elaborate and positively rewarding self monitoring scheme that allows the child to improve on his behavior effectively. A follow-up with the child's teacher indicated that the social outlook of the child had improved over the course of rehabilitation and the case further reiterates ability to rehabilitate individuals with stereotypic behavior. Estevis and Koenig [90] introduces a cognitive approach to reducing body rocking on an 8 year old congenitally blind child through self monitoring. Teachers or family members would tap on the shoulders of the child when he started rocking, while the child was taught to recite his own monitoring script. The authors conclude that rocking can be significantly reduced through notification to the individual combined with self monitoring.

Supporting such case studies of behavioral mannerisms, psychologists have been studying intervention and feedback as an integral component of social development. Feedback can be defined as the provision of evaluative information to an individual with the aim of either maintaining present behavior or improving future behavior [91]. According to [92], feedback is critical to social development because after an individual receives information about his or her performance, he or she can make the necessary modifications to improve social skills. Most social skills develop during early years and in order for children to evaluate themselves accurately and to modify social skills, it is essential that children to be given feedback [77][79], since without clear feedback, the children are unable to identify how their social behavior differs from others or is perceived by others in the environment [93]. Based on these studies there is enough evidence that feedback that offers intervention, possibly followed by a well planned self-monitoring program could benefit in reducing or controlling body rocking behavior.

1.4.3 Case study on a student how is blind

Technology specialist Shinohara [94][95][96], observed the everyday activities of a college student who was blind named Sara. Shinohara categorized Sara's daily needs into functional categories and has arrived with 5 important aspects in Sara's life where she needs assistance. These include (in order of importance) increased *socialization*, increased *independence* in doing things, increased *control* over things she does, *feedback* from objects around her, and increased *efficiency* in her activities. As seen from the list, socialization was a very important aspect of this college student's requirement. Shinohara concludes that design ideas for technology that supports socialization capabilities for people with visual impairment is of absolute necessity.

1.4.4 Summary:

In summary, individuals who are blind and visually impaired find it difficult in engage in social interactions and any technology that could be developed towards enhancing their access to social cues on an everyday basis might provide opportunities for both social learning and social rehabilitation. Currently, there exists no technology that is focused on developing social interaction assistance and rehabilitation.

1.5 Design of assistive technology towards social interactions:

Historically, the development of assistive devices has tended to be characterized by a technology-centric approach, which begins by asking ``What can we do?" This approach is often inspired by a newly emerging technology, and it tends to produce one-size-fits-all technological solutions to the obvious problems that people with disabilities might have already largely solved for themselves. One example of this type of technology-centric approach is a recent research project at Utah State University's *Robotic Guide* [97], which is a robot that employs multiple sensors to provide navigational assistance to users who are blind within a shopping environment. The user interacts with the robot through speech, a wearable keyboard, and audio icons. Although the multimodality approach offers significant advantages, feedback from the participants who are blind and who used the robotic guide indicated that the robot problems that reveal a very technology centric approach to the problem. The robotic guide moved at an average of 0.5 miles per hour which was too restrictive for any person. Additionally, the navigation system for the robot was based on SONAR, which caused jerky movements, and sometimes provided unreliable results, due to specular reflections and cross talk. The feedback from the focus group indicated that a major portion of decision-making was unnecessarily being off-loaded to the robot thereby restricting their freedom, which was viewed as an undesirable feature. This solution approached the problem from a navigational view point rather than as an accessibility issue. This is an important limitation because people who are blind can navigate independently through an environment using traditional methods, but they cannot read the printed signs, shelf tags, or package labels, nor can they determine the size, color, or pattern in a fabric of clothing in a retail shop. Focusing on the right problem is very important, especially while building assistive technologies.

Another problem with the technology-centered approach is that it often focuses only on the disabilities of the user, without taking into full account the user's abilities. For example, people who are blind are often able to perceive the presence of large objects in the environment around them. Ambient sound sources in the environment provide a form of audio illumination and the resulting sounds bouncing off of objects (or sounds shadowed by objects) allow a person who is blind to detect the presence of those objects. Sometimes in attempting to overcome a disability, developers of assistive devices unintentionally interfere with the user's abilities. For example, assistive devices that require the user to wear headphones or earphones [98] deprive the user of sounds that are vital to the perception of the environment.

In an attempt to develop an assistive technology for delivering facial expression information to individuals who are blind, [99] [100] developed a *haptic chair* for presenting facial expression information. It was equipped with vibrotactile actuators on the back of the chair in a three arm star configuration. The vibrations on the chair are related to the facial expression pattern of the interaction partner. For this experiment, the authors focus only on the mouth of the participant and deliver sad, happy and surprise expressions to the user. Experiments conducted by the researchers showed that people were able to distinguish between three basic emotions. However, this solution had the obvious limitation that the user needed to be sitting in the chair to use the system. The practical applicability of an assistive technology lies in its ubiquity in an everyday environment. Devices should be mobile and/or wearable for them to be useful in different professional and personal settings.

People with disabilities are not always able to perceive or interpret implicit social feedback as a guide to improving their social interaction. However, they might be able to use explicit feedback provided by a technological device. Rana and Picard [101] developed a device called Self Cam, which provides explicit feedback to people with Autism Spectrum Disorder (ASD). The system employs a wearable, self-directed camera that is supported on the users own shoulder to capture the user’s facial expressions. The system attempts to categorize the facial expressions of the user during social interactions to evaluate the social interaction performance of the ASD user. Unfortunately, the technology does not take into account the social implication of assistive technologies. Since it is being developed to address social interaction problems, it is important to take into account the social artifacts of technology. A device that has unnatural extensions could become more of a social distraction for both the participants and users than as an aid.

Current trends in pervasive and wearable computing allow miniature sensors to be placed on an individual discretely and inconspicuously. Vinciarelli et. al. [102] have described the use of discrete technologies for understanding social interactions within groups, specifically targeting professional environments where individuals take decisions as a group. They analyze the use of bodily mannerisms and prosody to extract nonverbal cues that allow group dynamics analysis. They rely on simple sensors in the form of wearable tags [103] which detect face to face interaction events along with prosody analysis to determine turn taking, emotion of the speaker, distance to an individual etc. Pentland describes these signals captured during group interactions as [104] *honest signals*. Some of his recent works [105] in the area of social monitoring hopes to capture these signals and provide feedback to individuals about their social presence within a group. The use of social feedback is illustrated elegantly in their work but their findings relied on sensors carried by all individuals involved in the study. Having everyone in a group wear sensors has proved to be a viable and productive approach for studying group dynamics. However, this approach is not viable as a strategy for developing an assistive technology for people who are blind, as it is not realistic to assume that everyone who interacts with that individual will wear sensors. Thus, it is important to develop technologies that are both egocentric and exocentric in nature, thereby allowing the monitoring of self and others in their environment.

In two independent experiments [106] and [83], researchers developed a social feedback device that provides intervention when a person with visual impairment starts to rock their body displaying a stereotypy. [106] designed a device that consisted of a metal box with a mercury level switch that detects any bending actions. The feedback was provided with a tone generator that was also located inside the metal box. The entire box was mounted on a strap that the user wears around his/her head. The authors tested it on a congenitally blind individual who had severe case of body rocking and they conclude that the use of any assistive technology is useful only temporarily while the device is in use. They state that the body rocking behavior returned to baseline levels as soon as the device was removed. Since the time of this experiment, behavioral psychology studies have explored short term feedback for rehabilitation [78], and these studies support the above observation that short term feedback is often detrimental to rehabilitation and subject's case invariably worsens. Unfortunately, due to the prohibitively large design of the device developed by these researchers, it was impossible to have the individual wear the device over long durations.

In [83] researchers used a 'Drive Alert' (driver alerting system that monitors head droop) to detect body rocking and provide feedback to a congenitally blind 21 year old student. The research concludes that they were able to control body rocking effectively, but the device could not differentiate between body rocks from any other functional body movements. This device, primarily built to sense drooping in drivers provides no opportunity to differentiate between a body rock and a functional droop. Use of such devices could only be negative on the user as a large number of false alarms would only discourage an individual from using any assistive technology.

1.5.1 Observations:

1.5.1.1 Observation 1:

Assistive technology designed towards social assistance should be portable and wearable so that the users can use them at various social circumstances without any restriction to their everyday life.

1.5.1.2 Observation 2:
Assistive technology designed towards social assistance should allow seamless and discrete embodiment of sensors or actuators making sure the device does not become a social distraction.

1.5.1.3 Observation 3:
Assistive technology designed towards social assistance should incorporate mechanisms embodied on the user to determine both self and other's social mannerism.

1.5.1.4 Observation 4:
Assistive technology designed towards social assistance and behavioral rehabilitation should be used over long durations in such a way that the feedback is slowly tapered off over a significantly longer duration of time.

1.5.1.5 Observation 5:
Assistive technology designed towards social assistance and behavioral rehabilitation should be effective in discriminating social stereotypic mannerisms from other functional movements to keep the motivation of device use high.

1.5.2 Summary:
In summary, any assistive technology developed towards social interaction assistance and rehabilitation will have to consider some of the important repercussions of social training, social actions and social impact of technology.

1.6 Sensing Non-verbal Cues:
As described in Section 1.2.1, most important aspects of the non-verbal communication cues are visual in nature. After speech, face delivers the most important cues for everyday interpersonal communication [2]. Further, people who are blind or visually impaired are very good at processing some part of the non-verbal cues through auditory signals. For example, they can sense large abrupt movements made by their interaction partners caused due to their cloths, furniture and other objects in the environment. It is the finer details of motion pertaining to the facial expression, hand gestures and eye gaze that becomes a problem in everyday interactions. Thus, introducing sensing technologies that can augment their abilities should be capable of providing access to the visual nature of some of the important non-verbal cues.

In the past two decades, machine vision technologies have advanced tremendously. This includes both the engineering aspects of developing ever smaller cameras and also the computing aspects of developing pattern recognition and machine learning tools that enable real-time analysis of images and videos. This advancement in image and video processing has resulted in advanced algorithms that are capable of sensing some of the important non-verbal cues that were identified in Sections 1.3.1 through 1.3.3. Though these techniques were not developed with social interaction assistance as being the focus, it is possible to adapt some of these techniques towards developing assistive technologies. In the table below non-verbal cues are presented along the rows and the columns present some of the popular computer vision algorithms. Each cell in the table presents appropriate research work that represents potential algorithm for specific non-verbal cue extraction. This is represented here as exocentric sensing as it allows a user to observe the field of view in front of them and understand the non-verbal cues.

1.6.1 Exocentric sensing:

	Scene Change Detection	Background Modeling	Face & Object Detection	Environment Analysis	Person Recognition	Clothing Recognition	Body Part Segmentation	Facial Feature Segmentation	Gender Race Recognition	Facial Motion Analysis	Body Motion Analysis	Eye Detection	Eye Tracking
Interaction Environment													
Proxemics		[107]	[108] [109]				[110] [111]						
Objects in the scene	[112]	[113] [114]	[108]										
Natural vs manmade environment	[112]			[115]									
Physical Characteristics of the Communicator													
Race & Body Color							[116] [117] [111]		[118]				
Body Shape					[119] [120]	[121] [122]	[123] [110] [116] [117] [111] [124]				[118] [120]		
Body Decoration					[125]								
Facial Hair								[126]					
Eye Glasses								[127]				[128]	
Clothing						[121] [122]							
Hair							[123] [129]						
Age					[130]								
Gender					[119]				[118]		[131]		
Identity					[132] [121] [133] [134] [135]					[136]			
Behavior of the Communicator													
Description of facial features								[137] [136]					
Body Mannerisms							[138] [139] [140]		[118]		[141] [142] [143] [144]		
Eye Gestures												[128]	[145] [146]
Gaze										[147]		[148] [149]	[147] [150]
Expressions & Emotions					[135]			[127] [137]		[151] [126] [127] [152] [153]	[154] [146] [144]	[155]	[145]
Personality					[119]		[139]		[118]		[143]		
Posture					[119]		[111]	[137]			[142] [126]		

The table above represents a comprehensive list of various technologies that exist in the computer vision and pattern recognition community that can offer solutions for providing non-verbal cues to people who are blind and visually impaired. While many interesting research questions exist under each of these sections, we focus on the two boxes that are shown in here as shaded cells. The first cell under "Face & Object Detection" along "Proxemics" and the second cell under "Facial Motion Dynamics" along "Expressions and Emotions" refer to the important non-verbal cues that can be extracted from the face of an interaction partner. The later chapters in this document will introduce these computer vision techniques that will be used for improving face detection and facial analysis.

1.6.2 Facial Expression Research:

Facial expression research has been popular among computer vision scientists for over a decade. Encompassed within the broader research issue of affect recognition, expression recognition has been growing alongside with other bodily sensor signal processing. A history of affect recognition from audio and visual sensors along with state-of-the-art algorithms can be found in [156]. The table below shows the state-of-the-art in vision based facial expression recognition. The table is not a comprehensive representation of the algorithms that have been developed, but it provides a brief glimpse into the various feature selection algorithms, learning methodologies and classification paradigms that are being used. While the state-of-the-art in expression recognition research is very high, from the perspective of developing real-time systems that can provide assistive technology support is still not at a pragmatic stage. This can be attributed to some important concepts that are not being addressed by the computing community. These include.

1. Most research is focused on developing classification algorithms for facial expressions focused on seven basic expressions as described by Ekman and Friesen [67], namely Happy, Sad, Surprise, Angry, Disgust, Fear and Neutral.
2. The research works primarily with standard posed expression databases that are not very well representative of the spontaneous expressions that occur during everyday interpersonal interactions.
3. While facial expression recognition has been analyzed from a classification perspective, in assistive technology solutions, it is more useful to develop a regression framework as it will allow access to subtle changes in facial mannerisms of the interaction partner.
4. Most important, these algorithms have not been developed from the perspective of delivering the information back to a human (except certain assistive aides like [101]). They have only focused on using these classifications in determining the affect of the user from a human computer interaction perspective. While this will allow enhanced interactions in human-machine interfaces, the technology cannot be used effectively as an interface in human-human interaction. The focus of the social interaction assistant is to enhance the interactions between humans.

Reference	Features	Classifier	Performance					
			Exp	Per	Class	Sub	Samp	Acc (%)
[157]	AAM	SVM	S	I	2	21	?	81
[158]	Gabor	SVM + HMM	S	I	3 AUs	17	V	98
[159] [160]	Gabor	AdaBoot SVM	S P	I	17 AUs	119+12	I	93+90.5
[161]	12 motion units	Tree DBN HMM	P	D I	6	5 + 53	V	66.5+73.2
[162]	Shape Models, Gabor	LDC	S	I	3 AUs	21	I	76
[163]	24 facial points	DBN	P	D	6	30	V	77
[164]	Intensity	NN	P	?	7	?	I	68
[165]	Shape fea, Optic flow	C4.5 Bayes Net	P	?	8	4	I	100
[166]	FAPs	Neurofuzzy network	S	I	3	?	I	78
[167]	Shape fea	DBN	S	?	2	8	V	95.3
[168]	Facial and head gesture	GP SVM HMM NN	S	?	2	8	V	86
[169]	Pixel diff of mouth	GP SVM HMM NN	S	I	2	24	V	79
[170]	Intensity of face	Decomposable model	P	I	6	8+16	V	61
[171]	Gabor	AdaBoost SVM	S	I	2	26	V	72
[172]	AAM	SVM	S P	I	AUs	100	?	95
[173]	Facial profile	Rule-based	P	I	27 AUs	19	V	86.3
[174]	Frontal & profile facial points	Rule and case based	P	I	9	8	I	83
[175]	12 motion units	kNN	S	I	4	53+28	V	93+95
[176]	Gabor	AdaBoost DBN	P	I	14 AUs	100+10	I	93+93
[177]	Motion history	SNoW kNN	P	I	15 AUs	19+100	V	61+68
[178]	8 facial points	Gentle Boost SVM	S P	I	2	27+32+65	V	90
[177]	20 facial points	Gentle SVM	S P	I	2	52	V	94
[179]	Shape fea & Intensity	NN	S	?	7	14	I	84
[180]	3D surface	LDA	P	I	6	60	I	83
[181]	Geometric ratio	GMM	P	I	4	47	I	75
[182]	Harr	AdaBoost	P	I	11 AUs	?	I	92
[159]	Intensity	kNN HMM	S P		6	97+21	V	90.7 + 82
[183]	Texture with LPP	SVDD	S	D	2	2	I	87

exp: Spontaneous/Posed expression,
per: person Dependent/Independent,
class: the number of classes,
sub: the number of subjects.
samp: sample size (the number of utterances),
acc: accuracy,
?: missing entry.

1.6.3 Summary:

In summary, developing algorithms that can process the facial features of interaction partners for developing social interaction assistive technologies will require that they be able to

1. *Deliver subtle facial movements to the users of the technology.*
2. *Allow the users to cognitively process spontaneous expressions.*
3. *Provide real-time tracking of facial movements in an unobtrusive manner.*
4. *Offer a mechanism to deliver these high bandwidth facial data back to the user in an effective manner.*

1.6.4 Egocentric sensing

From the discussions above, egocentric sensing mostly pertains to the behavior patterns of an individual who is blind or visually impaired. Specifically, we are monitoring their body movements and detecting stereotypic mannerisms. Recently, human activity detection and recognition using motion sensors have taken a front seat in technology and behavioral research. This is due to the availability of micro mechanized electronic systems (MEMS) that have started to implement complex mechanical systems at a micro scale on integrated circuit chips. These offers advantages like reliability, cheaper cost of production, smaller form factor and above all extremely precise measurement with least or no maintenance. One such sensor is the accelerometer that is capable of measuring the effect of gravity on three perpendicular axes. When mounted on any moving object, the opposing motion (opposing gravity) of the entity allows these sensors to measure the speed and direction of motion. Integrating the magnitude and orientation information over time it is possible to accurately measure the exact motion pattern of the moving entity. These accelerometers have been used by researchers to track motion activity in almost every joint of the human body [184]. Researchers have used single, double or triple orthogonal axis accelerometers to detect various activities of humans

In [185], the researchers provide a nice discussion on some of the ambulatory movements that can be extracted from accelerometers. Five bi-axial accelerometers are used in [184], along with a decision tree classifier to detect and recognize 20 different activities of daily life. They report a recognition rate of over 85%. In [184], the authors evaluated different meta classifiers for recognizing seven lower body motion patterns from a single biaxial accelerometer data and reported the best performance for boosted Support Vector Machines (SVM) [186] with a subject independent accuracy of 64%. Since each dimension of the accelerometer data is similar to audio waveform, popular Hidden Markov Models [187] can be used to learn motion patterns. Reference [188] used HMM to learn the accelerometer data for specific tasks performed by participants and reports a recognition rate of over 90%. In [189], researchers have used two accelerometers placed on the arms of Kung-Fu practitioner and report a recognition accuracy of 3 Kung-Fu arm movements at 96.6%. Research work [190] demonstrates the use of accelerometer data to not only recognize activity, but also localize people within a building. Though the technique is rudimentary, the authors report a high accuracy in recognition of activities while localization still remains a research topic. [191] have demonstrated the use of accelerometers in not only monitoring movements, but also static posture of the human body. They report a recognition rate of 95% using four sensors placed on the chest, thigh, forearm and wrist of participants. Extending this work, [192] have demonstrated an assistive technology solution that uses low cost accelerometers on stroke patients and monitor their posture and walking patterns. Using this information, a feedback is provided to the patient to self-correct their posture and walking pattern. While these motion sensors are capable of extraction very subtle motion patterns, they have not been exploited in detecting stereotypic mannerisms.

1.6.4.1 Summary:
In summary, with the current technology in motion sensors and the ability to provide accurate measurement of motion patterns, stereotypic body mannerisms can be modeled, provided enough training data is acquired for the particular body mannerism that is of interest.

1.7 Delivering Non-verbal Cues:

The human visual system is a very high bandwidth channel through which immense amount of data is acquired and processed. Providing an auxiliary channel that can handle the immensity of this data is impossible. It is only possible that an alternate modality of information could be made available through assistive technologies which can be used by the individuals who are blind when they deem necessary to access certain non-verbal cues from their interaction partners. Historically, this alternate channel for information delivery has been auditory signals. Various types of information have been encoded into audio signals and delivered in the form of varying frequencies, amplitudes and pulses. But this can only introduce a higher cognitive load on the individuals as they are already processing most of their environmental data in the form of auditory signals. It is imperative that they should not be overload with more information on this channel. To this end, haptics (sense of touch; a mostly unexplored area of human interface design) is intorduced as an alternate modality for information delivery.

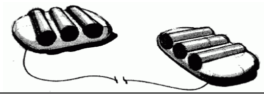
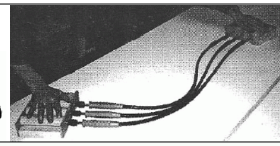
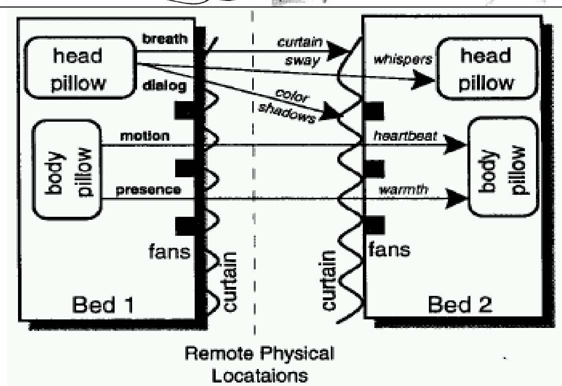
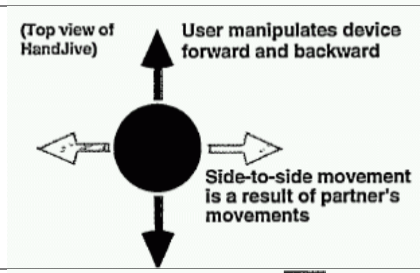
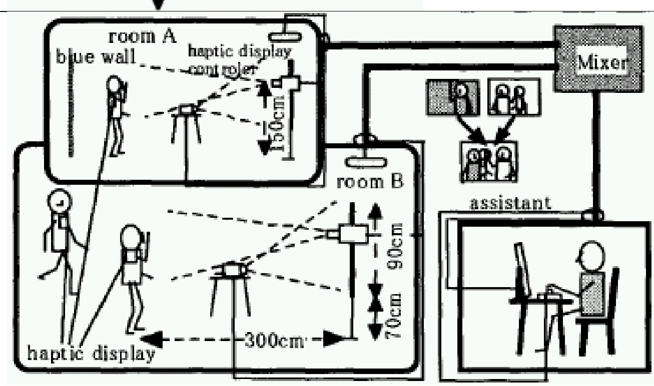
1.7.1 Haptics:
Recent developments in the area of haptics have resulted in innumerable number of interfaces and interface design principles. Researchers have explored various dimensions of touch (associated with various mechanoreceptors and thermoreceptors on the human skin) including vibratory stimulation (Pacinian corpuscle [193] & Meissner's corpuscles[194]), pressure and texture stimulation (Merkel cell [195]), temperature differential (thermorecptor [196]), and proprioception (Ruffini Ending [197]). Given these dimensions of haptic actuation and the very large surface area of the human skin, it is possible to develop various technologies that can deliver data in various modalities that can work independently or coactively with the auditory system.

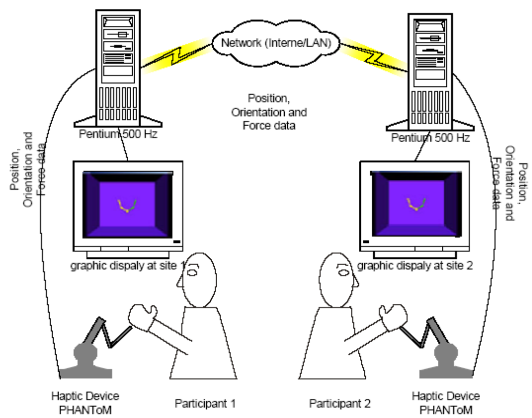
While the entire human body is covered with skin, the brain mapping of the various neural receptors is not consistent across regions. Based on the site on the human skin, the density of the receptors and their mapping to the brain varies. The image of a human exaggerated based on the mapping of the receptors is referred to as the somatosensory homunculus [198]. As shown in the Figure 4, the homunculus has very large hands, lips and genitals. These areas are very sensitive to touch and have very high resolution when compared to other parts of the body. This offers a mapping of where haptic based delivery of information could be places depending on the data bandwidth.

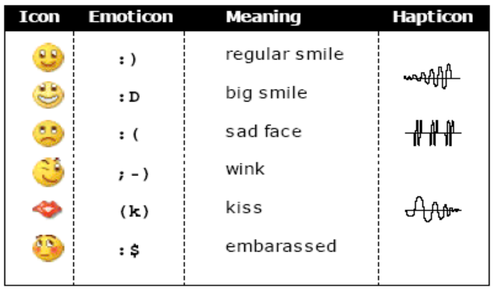
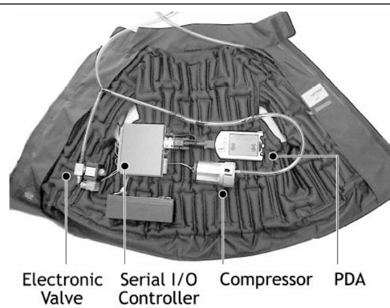
Figure 4: The somatosensory homunculus with exaggerated body parts based on the mapping of haptic receptors in the brain.

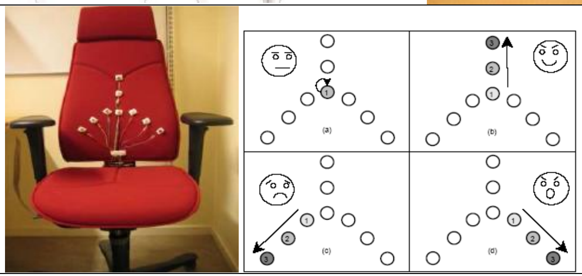
1.7.2 Haptic interfaces for delivering interpersonal information:

Haptics technology has been heavily embraced by the human computer interface community in the past two decades primarily due to the penetration of computing resources into everyday lives of individuals. This has resulted in the emergence of a new area of interface design that focuses primarily on delivering interpersonal information across distances thereby allowing remote interpersonal interactions, both professional and personal. Similar work in the area of telerobotics for surgery, teleoperation of unmanned vehicles, gaming etc have exploded research towards developing haptic interfaces. Below we present a comprehensive assessment of various interfaces that have been developed towards interpersonal communication.

Name	Device	Ref	Actuations	Major Organ	Non-verbal Cue	Application	User Experience
inTouch	 	[199]	Vibration Pressure Texture	Hand	Touch	-Interpersonal communication through remote touch	No Testing
The Bed		[200]	Pressure Texture Temperature	Body	Touch	-Remote interpersonal intimate communication	Self report - System found to produce feelings of intimacy.
HandJive		[201]	Pressure Proprioception	Hand	Handshake Touch	-Interpersonal communication through new cueing language	
HyperMirror		[202]	Pressure	Shoulders	interpersonal distance, relative position, crossing paths	-Remote crossing of paths. -Initiating interaction in strangers across distance. Tap to initiate conversation.	Eye contact was made across distant users. Tap signal aroused attention. Crossing paths initiated conversations.

VinroBod		[203]	Pressure Temperature	Hands	Touch	-Convey remote interpersonal cues.	15 subjects found the device useful and intuitive
What's Shaking		[203]	Vibration Temperature	Hands	Proxemics	-Heat corresponds to the number of people. -Vibration corresponds to the amount of activity in the environment.	12 subjects found the glove intuitive and were able to identify activity around them.
Tele Handshake		[204]	Proprioception	Hnads	Touch	-Remote handshake between interaction partners	65% Satisfaction 55% Convincing 60% Intiutive

Com Touch		[205]	Vibration Pressure	Hands	Touch Emotions	-Bidirectional operation. -Remote participant squeezes one end and a recipient at the other end feels vibrations	-24 subjects. -Subjects came up with their own cueing. -In Desert Survival Task, 15 items were sorted based on importance and 5 were ranked. -83% of participants used atleast one gesture. -67% developed their own gestures
Haptic Instant Messenger	 Icon / Emoticon / Meaning / Hapticon :) regular smile :D big smile :(sad face ;-) wink (k) kiss :$ embarassed	[206]	Audio Vibrations	Hands	Emotions	Based on user selections at a remote location, haptic and audio codes are transmitted to the receiver.	No user testing
Hug over Distance	 	[207]	Pressure Proprioception	Upper Body	Touch Hug	At one end the user rubs tummy of a stuffed toy and based on the pressure applied, air bags are filled at the remote end to simulate hug.	- Air compressor at the receivers end makes a lot of noise - Six couple focus group found the concept weird.
TapTap		[208]	Pressure	Shoulders	Touch Tap	Solenoids and vibrators used on the shoulder to simulate tapping.	- 8 men and 8 women tested on the device found based on the tap, it reminded them of someone.

United Pulse		[209]	Vibrations	Finger	Intimacy	-Vibrators on the ring stimulated to initiate communication between remote couple. -Simulated heart beats were delivered	-20 couples tested with the device. - 22 liked the idea. - 5 were irritated.
Haptic Chair		[100]	Vibrations	Back	Emotions	- Vibrations corresponding to emotions are delivered to the back of the user. - Has sensing of the emotions inbuilt through vision technologies	- 3 expressions tested. - 100% recognition on expressions. - 10% of participants complained of cognitive load.

While most of the devices presented above were developed for the application of interpersonal communication, their focus was restricted to a specific non-verbal cue, especially intimacy. The Haptic Chair [100] is one research that comes close to developing an assistive technology for people who are blind. Unfortunately, the device is not portable and any assistive technology should not be restrictive to the users, especially in a professional setting. Further, the researchers have tried to acquire the emotion data from videos by analyzing the mouth region of the interaction partners. This works in scenarios where the participants are posing expressions and not in spontaneous emotion generation. Verbal movements of the mouth can render the system ineffective due to random movements of the mouth.

As explained above, the number of haptic devices possible is innumerable as the form factor and modality of delivery can vary significantly. Two important form factors are explored in detail below as

1. The vibrotactile belt, develops on the intuitive cueing that is possible in haptic technology for low bandwidth non-verbal cues, like number of people in the viscinity, proxemics, eye gaze of an interaction partner etc.
2. The vibrotactile glove, that is placed on the human hand, which has the highest haptic sensitivity thereby allowing us to deliver high bandwidth non-verbal cues like facial mannerisms.

1.7.3 The Vibrotactile Belt:

Vibrotactile cues are vibratory signals defined by signal frequency, intensity, rhythm, and duration [210] of the vibration in contact with the human body. Vibrotactile cues have found uses in a variety of application areas including human navigation [211] [212] [213], human spatial orientation [214][215], human postural control [216] and human communication [210]. The idea of using vibrotactile cues on a haptic belt for information delivery is not a new idea. However, the use of vibrotactile cues for non-verbal communication during social interactions is novel and provides an exciting opportunity to provide assistance with daily tasks to individuals who are blind. This section introduces several approaches for using vibrotactile belts to convey navigation and/or orientation information, which inspired the design of our haptic belt.

In an early haptic navigation system for individuals who are blind [211], Ertan *et al.*, proposed a tactile display (worn on the back) consisting of a 3x3 array of tactors that convey directional information through pulsing columns and rows. In [212], the authors proposed the ActiveBelt, a haptic belt to guide the user to a destination using eight tactors placed around the waist, a GPS unit and an orientation sensor. Another system for human navigation is a tactile vest proposed by Jones *et al.* [213], which utilizes a 3x3 array of tactors placed on the back to convey directional information.

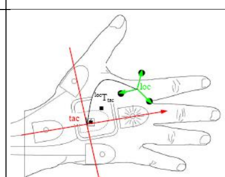
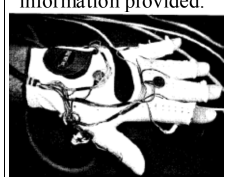
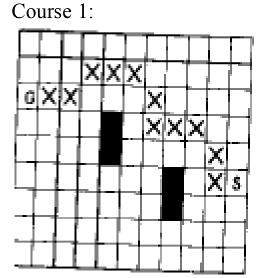
Another application of vibrotactile cues is the Tactical Situation Awareness System (TSAS) [214], which is a tactile suit designed to help reduce spatial disorientation that is sometimes experienced by pilots in flight due to a lack of visual cues. The TSAS uses vibrations to indicate critical information such as the direction of the gravity vector. Similarly, tactile displays have been developed to help astronauts compensate for spatial disorientations [215]. Finally, tactile display devices have been developed to assist people with damage to their vestibular system. For example, in [216], balance control is achieved using a haptic belt system composed of a tilt sensor and three rows of tactors used to indicate body tilt information.

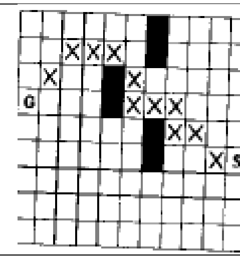
A variety of belt designs have been proposed in the literature. Most of these designs are motivated by a particular application. Furthermore, most of these implementations lack usability and performance studies as the central focus tends to be a proof of concept. In fact, usability and performance are rarely discussed. Implementations often have excessive cabling and bulky modules, while the required robustness and rigidity for real-world use are completely ignored. Table II presents a sample of seven haptic belts, chosen based on maturity and availability of information regarding design choices and implementation details. Table below provides a comparison of these belts, based on the functionality design requirements. A cross indicates that a feature is available, whereas a blank entry indicates that the feature is either not available or its availability is unknown.

Function	[217]	[218]	[212]	[219]	[220]	[221]	[222]
Amplitude	X			X	X		X
Frequency	X		X		X	X	X
Timing	X	X	X		X		X
Location	X	X	X	X	X	X	X
Add/Del motors	X			X			
Adjust tactor position	X	X		X		X	
API				X	X		
Wearable		X	X	X	X	X	X
Wireless		X	X	X	X	X	X

1.7.4 Vibrotactile Glove:

As can be seen from the homunculus in Figure 4, the hand is represented in the brain by a very large somatosensory cortical area. This allows for the human hand to be a receptor for large bandwidth of information. Vibrotactile stimulations have been used in the past to take advantage of the human haptic sensory system and hands form a perfect medium for conveying large variations in such stimulations. The palm of the human hand is haptically more sensitive, when compared to the hairy side of the hand. This has prompted researchers to explore the palm as their medium for communicating haptic cues. Unfortunately, any hindrance to the palm of the hand renders the hand functionally useless. If an assistive technology has to use the hand to deliver haptic cues, it is important that the hairy side of the hands be used. The table below presents some of the important research work in that uses vibrotactile gloves for delivering information in various applications. Detailed description of the application of the glove, the structure of the glove and the accuracy of the system working are shown in the table also.

Ref	Application	No. of vibrators	Location of vibrators	Vibration Pattern	Encoding	Experiments	User Study
[223]	Convey color information to people who are blind.	3	- Distal phalanges of index, middle and ring fingers. (T) - Three phalanges of the index finger. (O)	- Continuous on all three vibrators. (S) - 0.5s time gap between vibrators. (D)	- Encode R, G and B channel to each of the 3 vibrators. - Amplitude of vibration proportional to the intensity of the color channel.	- Convey only colors individually (C). - Allow users to explore a down sampled color image using a mouse. (I)	- 5 participants who are blind. -2 sighted participants. - COS: 71% - CTS: 87% - ITS: 100% - IOD: 67% - IOS: 92% - COD: 87% - CTD: 90%
[224]	Vibrotactile cueing to improve target acquisition in virtual 2D environment using mouse as input.	4	-2 on the lower part of the palm just above the wrist. - 2 on the back of the lower palm just above the wrist.	- 100ms vibratory cues to indicate direction of the target and on-target signals.	- Frequency of the vibration was proportional to the direction and distance from the target location. - Two vibrators were turned on to indicate arrival on a target.	- Expt 1 tested vibrators on the front and back of palm. - Expt 2 tested continuous distance cueing with suppressing or increasing frequency as the target is approached.	- The location of the tractors did not have an effect. Front and Back worked the same, - Suppressing the frequency as the user approaches the target worked better than enhancing.
[225]	Vibrotactile array for delivering distance to an obstacle from a wheelchair driven by a visually impaired person.	9	Array on the front of the palm in a 3x3 matrix.	- Warning signals - Spatial obstacle location signal. - Direction conveyance to the user.	- Warning signal vibrates all vibrators. - Spatial location of an obstacle is sent in the particular motor with near, medium and far range to obstacle. - Direction cue vibrates the center motor with two pulses and then vibrates motor of the desired direction.	- No user testing done yet	- No user testing done yet
[226] [227]	Vibrotactile cues for navigating surgeons hand during surgery.	4		- Continuous vibrations based on the amount of off target displacement	- Optical tracking of visual markers on the surgeons hand is translated to vibrotactile cues to give off-center information.	- Subjects were required to move a surgical tool to the target location.	- Subjects react to varying impulse input as required. No quantification provided in the paper.
[228]	Field of view in front of individual who is blind is captured with a camera and translated to vibrotactile cues corresponding to a depth map.	?	No specific information provided. 	- Magnitude of vibration is directly proportional to distance to obstacle. - Frequency of vibration is inversely proportional to the confidence in depth measurement.	The image from the camera is used to determine a depth map of obstacles in front of the user and is translated into vibrotactile cues.	Two obstacle courses were set within the labotatory environment and the participants were required to navigate the course. Course 1:  Course 2:	- 9 participants, 3 blind and 6 with low vision. - Course 1: Travelled the minimal hitting path 65% with their existing navigation aid and increased to 75% with the glove. - Course 2: Travelled the minimal hitting path 65% with their existing navigation aid and decreased to 57% with the glove.

							
[229] [230]	Framework for delivering haptic data along with audio video data from an entertainment perspective. Specifically, adding a haptic layer to the MPEG 4 audio video coding.	76	Vibrotactors are added all over the glove both on top and bottom of the hand. No specific configuration pattern is discussed in the paper.	Custom designed vibration patterns that take into account all the vibrators on the glove.	Manually encoded by entertainment specialists based on the movie and the scene.	No user study.	No user study.
[231]	Using vibrators to convey slip information in a prehensile glove.	5	Fingertips of the five fingers.	Motion sensors (optical motion sensor similar to the one used in an optical mouse) mounted outside the glove on the finger tips measure the slip of an object. The slip information measured as optic flow is conveyed to the vibrator as varying frequency.	Slip motion is proportional to the frequency of vibration.	Users placed the glove on a surface that was laterally pulled from under the glove and the reaction time was measured by asking the participants to press a button with their free hand. Experiment was conducted with bare hands, with a prehensile glove without vibrators and with the slip glove.	12 subjects. Mean reaction time: Bare hand: 0.214s Normal Glove: 1.669s Slip Glove: 0.483s Percent Failure: Bare hand: 0% Normal Glove: 27.8% Slip Glove: 5.6%

1.7.5 Summary:

Vibraotactile cueing provides immense opportunity to deliver high bandwidth information through the use of somatosensory channels. Unfortunately, not much research exists in the development of delivery devices for assistive aid. Research is needed in designing high bandwidth delivery form factors and determining the right encoding on the haptic signals to allow effective delivery of information.

1.8 Research Questions:

Social interactions are vital for everyday living and it is very important for the development of social learning and social feedback in human interpersonal communication. Most part of this communication happens through the use of visual non-verbal cues that put people who are blind or visually impaired at a disadvantage. While the problem of social interaction assistant remains unattended, couple of existing computer vision and signal processing technologies offers possibility of building such assistive device. To this end, we identify some of the important research questions that need to be addressed towards developing effective social interaction assistant.

1. What non-verbal cues are important from the perspective of an individual who is blind or visually impaired?
2. What assistive technology framework can be developed towards addressing the important social needs of individuals who are blind and visually impaired?
3. How effectively can the non-verbal assistive and rehabilitative cues be identified from state-of-the-art sensors used in developing the above social interaction assistant framework?
    a. How effectively can social interaction cues be identified from an exocentric perspective using camera as the primary input sensors?
    b. How effectively can social interaction cues be identified from a egocentric perspective using body motion sensors?
4. How effectively can data be delivered back to the users of the social interaction assistant by using haptic processing technologies?

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