Decoding Actions and Emotions in Deaf Children: Evidence From a Biological Motion Task

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This study aimed to explore the recognition of emotional and non-emotional biological movements in children with severe and profound deafness. Twenty-four deaf children, together with 24 control children matched on mental age and 24 control children matched on chronological age, were asked to identify a person’s actions, subjective states, emotions, and objects conveyed by moving point-light displays. Results showed that when observing point-light displays, deaf children showed impairments across all conditions (emotions, actions, and moving objects) compared with their chronological age-matched controls but showed no differences across subjective states. The results are supportive that deaf children present developmental delays in their biological motion apart from the ones relative to their own mental state, and this may be interpreted in relation to the expertise they have acquired in decoding action toward themselves. The findings are discussed in relation to deaf children viewing motion stimuli very differently to hearing children.

Deficits in emotional and social interactions have been widely reported in deaf children (Kusché, Garfield, & Greenberg, 1983; Vernon & Greenberg, 1999; Wauters & Knoors, 2007; Weisel & Bar-Lev, 1992). Since the development of linguistic skills and socioemotional competencies have been closely linked (e.g., Malle, 2002), these deficits have been consistently attributed to delays in language acquisition and/or reduced opportunities to converse about personal experiences with other people (e.g., Peterson & Siegal, 1995, 1998).

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Among the social impairments documented in deaf populations are problems in understanding other people’s emotions (e.g., Rieffe & Terwogt, 2000). These difficulties have often been interpreted as theory-of-mind (ToM) deficits, thereby implicating a lack of awareness of other people’s mental states. Deficits in ToM abilities have been most commonly reported in congenitally deaf children of hearing parents who have not been exposed to sign language (Peterson & Siegal, 1995, 1998; Remmel & Peters, 2008; Russell et al., 1998; Steeds, Rowe, & Dowker, 1997), suggesting an early and specific need for interactions with a native speaker. Indeed, deficits in ToM abilities have also been observed in late-signing deaf children (Peterson & Slaughter, 2006). Given that the ability to understand emotions is related to measures of social competence (Custrini & Feldman, 1989), ratings of peer popularity and likeability (Denham, McKinley, Couchoud, & Holt, 1990), and academic achievement scores (Nowicki & Duke, 1992), questions about the ways that deaf children access emotion information are important.

Experimental studies into social abilities in deaf populations have emphasized delays in understanding other people’s emotions (e.g., Dyck, Farrugia, Shochet, & Holmes-Brown, 2004). However, to date, studies testing facially expressed emotions in the deaf have produced equivocal findings. Early studies indicated that deaf children do make more errors in recognizing facial expressions of emotion than do hearing children, and deficits are greater in those with prelingual rather than postlingual hearing loss (Bachara, Raphael, & Phelan, 1980; Schiff, 1973). However, in later studies where deaf and hearing children were presented with simple emotion-recognition tasks that involved emotion matching, group differences did not emerge (Hosie, Gray, Russell, Scott, & Hunter, 1998).

It is noteworthy that the majority of research studies that have addressed questions about emotion-recognition abilities in deaf populations have relied on photographic, thus static, representations of facial expressions (e.g., Dyck et al., 2004). However, dynamic faces have been argued to give a more accurate measure of performance as it is similar to what we experience in everyday life, whereas static faces may underestimate a person’s ability to recognize emotions (Moore, 2001). The motion in dynamic faces provides independent information about emotional expression that is not available in posed, static faces (Hill & Johnston, 2001), and research has shown that recognition and discrimination of emotions is superior in dynamic, compared with static, displays (e.g., Bould & Morris, 2008; Wehrle, Kaiser, Schmidt, & Scherer, 2000).

Although it is clear that expressions of emotion are powerfully conveyed by faces, movement of body parts is also important as both context and gestures provide vital sources from which we derive emotional meanings (e.g., Clarke, Bradshaw, Field, Hampson, & Rose, 2005; Pollick, Hill, Calder, & Paterson, 2003). For example, when point lights are attached to the joints of an invisible moving human in a dark room, the visual system can rapidly and reliably distinguish these from similar motion patterns that do not emanate from human beings (e.g., Johansson, 1973). Indeed, a number of studies have shown that complex information, such as emotions, desires, intentions, and dispositions, expressed by a single person or mutual agents, can be reliably conveyed using point-light cues (Blake & Shiffrar, 2007; Chouchourelou, Toshihiko, Harber, & Shiffrar, 2006; Clarke et al., 2005). Although sensitivity to point-light displays (PLDs) substantially increases during the first 5 years of life (Pavlova, Krageloh-Mann, Sokolov & Birbaumer, 2001), evidence suggests that such abilities are visible at the earliest stages in perceptual development (e.g., Bertenthal & Pinto, 1994) and may be implicated in the development of nonverbal social communication skills (Dittrich, Troscianko, Lea, & Morgan, 1996).

For individuals who are deaf or hard of hearing, recognition of emotional expression from body gesture would appear to be vital. However, relatively little is known about the extent to
which deaf children utilize such cues. One recent strand of research has provided evidence that
deaf children adopt alternative perceptual strategies to hearing children. For example, they rely
more heavily on motion cues while gauging when to cross a busy road (Bosworth & Dobkins,
2002) and when comprehending critical linguistic information in the hand movements of
British sign language (Corina et al., 2007). It is surprising, given both the importance of
motion for emotion understanding and findings suggesting atypical motion processing in deaf
children, that motion processing in communication domains has not been widely studied in
this population.

Evidence supporting the benefit of using motion cues to improve understanding of socio-
emotional content has been investigated in other clinical populations, including autism spectrum
disorder (ASD). This work has built on earlier findings showing deficits in ToM and emotional
face processing (e.g., Celani, Battacchi, & Arcidiacono, 1999). A study carried out by Parron
et al. (2008) investigated action and emotion interpretation using PLDs in children with
ASD. These findings revealed a dissociation with impaired performance relative to age-
and intelligence-matched controls on PLDs with emotional value, but no impairment relative to
controls on PLDs depicting simple personal actions, subjective states, and objects. These
findings were consistent with previous studies showing a selective impairment in interpreting
PLDs with emotional content in autism (Hubert et al., 2007; Moore, Hobson, & Lee, 1997).

As previous studies into emotion recognition in deaf children have largely utilized static
representations of faces, the nature of the emotion-processing deficit is currently unclear. To
capitalize on their proven strengths in motion processing (Bosworth & Dobkins, 2002; Corina
et al., 2007), we adopted the methods used by Parron et al. (2008) and used PLDs to test the
assumption of a global emotion-processing deficit in deaf children. Point-light techniques have
been used previously with deaf populations to assess how sign language influences action
processing (Knapp, Cho, & Corina, 2008). In the Knapp et al. study, adult deaf signers and hearing
nonsigners were asked to detect signed and pantomimic point-light movements that were
embedded in a field of white-noise dots. While the hearing nonsigners found it harder to detect
differences in sign movements than in pantomimic movements, deaf subjects showed a similar pat-
tern of performance across the two conditions. This difference suggests that deaf participants—
compared with hearing participants—do not differentiate signs from other nonlinguistic gestures.

In the current study, children with severe or profound hearing difficulties and hearing controls
were tested on their ability to recognize a person’s actions, subjective states, emotions, and
objects conveyed by moving PLDs. The study aimed to ascertain whether children with severe
or profound hearing loss recognize basic human actions represented by PLDs and to determine
whether discrimination performance is influenced by the emotional content of the displays.

METHOD

Participants

Participants were 24 children with severe or profound bilateral, congenital deafness. The sample
included 10 boys and 14 girls, aged 6;8 to 16;10 (M\text{age} = 13;3; SD = 37 months). All of these
participants attended mainstream schools with units specializing in the education of hearing-
impaired children. Of these 24 children, 11 were profoundly deaf (hearing loss >90 db) and
13 were severely deaf (hearing loss >70 db). None had known associated medical disorders at the time of testing, and visual examination was found to be normal. Neuropsychological evaluation was conducted by means of the Standard Progressive Raven Matrices (Raven, Court, & Raven, 1992; range = 67–123, \( M = 83.1, SD = 14.8 \)). Mental-age scores \( (M_{\text{mental age}} = 9.3; \ SD = 28 \text{ months}) \) were derived from scores on the Standard Progressive Raven Matrices. The children were matched on nonverbal ability, as deaf children are thought to rely more heavily on nonverbal cues in the development of emotions. Further justification for matching children using scores derived from the Raven Matrices is provided by Albanese, De Stasio, Chiacchio, Fiorilli, & Pons (2010), who found nonverbal intelligence to exert an effect on improving children’s emotion understanding.

Two groups of typically developing children also participated in the study. The children were recruited via state schools, and class teachers, who assisted in participant recruitment, were asked to nominate children of average intellectual ability. None of these children had overt physical handicap, learning difficulties, or known neurological/psychiatric deficits, and all had normal-to-corrected vision and normal audition. The 24 children in the first comparison group were individually matched to the children in the deaf group for gender and mental-age scores (MA-matched; aged 4;3 to 13;4; \( M_{\text{chronological age}} = 9.5; SD = 25 \text{ months}) \). In addition to gender, the 24 children in the second comparison group were individually matched to the children in the deaf group for chronological age (CA-matched; aged 6;4 to 17;0; \( M_{\text{chronological age}} = 12.5; SD = 28 \text{ months}) \). This matching procedure has been adopted in a number of published studies using PLDs (e.g., Hubert et al., 2007; Parron et al., 2008) and allows interpretation of results in terms of developmental delay and/or developmental deviance. By comparing to a CA-match group, any individual differences found in deaf children would suggest developmental delay. In contrast, if deaf children are found to be different than both MA- and CA-matched groups, then this difference can be accounted for by atypical deviance in that behavior (Hodapp, Burack, & Zigler, 1990; Leonard, 1998).

Materials

Tasks and stimuli were chosen to replicate the procedures initially used in Moore et al. (1997, Experiments 2 and 3) and further replicated in both Hubert et al. (2007) and Parron et al. (2008). Stimuli were video clips each of 5 seconds duration. They showed dynamic PLDs of a male actor performing 14 actions. There were also a further five control stimuli of manipulated PLDs of everyday objects: a ball rotating, a pair of kitchen balance scales moving as a weight was added, an ironing board being opened and closed, a dustpan and brush sweeping, and a saw in action. In each case, 10 reflective point lights were distributed across the object in a manner that meant the object was not recognizable from a still image. There were also five clips of the actor displaying subjective states—actions that reflect an underlying state such as itchiness or tiredness—and five clips of the actor depicting emotional actions—happy, angry, etc. (a complete list of the video clips is provided in Table 1). The same stimuli was included as in previous research. This included stimuli without emotional valence (action and object) and stimuli with emotion valence (emotion and subjective states). The action condition remained largest to reflect the fact that the action repertoire is thought to be much bigger than both the emotional- and subjective-state ones.
Procedure

Participants were individually tested in a quiet classroom located in the school or day-care center. They were seated in front of a computer screen at a viewing distance of 60 cm. Participants were asked to watch the movies and to describe what was happening. Participants were told that they were going to be presented with short movies and that they were going to be asked to communicate orally or through sign what they had seen. All responses were recorded by the experimenter, who was an experienced signer (although not fluent). However, a teaching assistant fluent in sign was also present during these sessions to ensure that the children understood the tasks and that the children’s responses were reported correctly. Responses were scored as correct when participants accurately captured the object, the action, the state, or the emotion portrayed by the PLDs or provided a sign that approximated the action or state. It is important to note that responses were also considered correct when a participant provided a synonymous word that indicated the object, the action, the state, or the emotion captured by the PLDs. In the emotion condition, responses were scored correct if they captured the emotional experience. Each participant completed a total of 29 trials: 14 in the action condition, 5 in the subjective-states condition, 5 in the emotional-states condition, and 5 in the object condition. The order of trial presentation was randomized for each subject.

RESULTS

Performance Accuracy across Conditions

A $3 \times 4$ analysis of variance (ANOVA), with group (deaf, MA-matched, CA-matched) as a between-subjects factor and condition (actions, subjective states, emotions, objects) as a within-subjects factor, was conducted using the mean accuracy rates as the dependent variable. This analysis revealed a main effect of group, $F(2, 69) = 5.19$, MSE = .90, $p < .01$, $\eta^2 = .13$. Tukey post-hoc analyses indicated that deaf participants produced significantly more errors than did CA-matched participants ($M_{\text{difference}} = 0.43$, $p < .01$), but they indicated no difference compared with MA-matched participants ($M_{\text{difference}} = 0.26$, $p = .14$). There was no difference in accuracy between MA- and CA-matched participants ($M_{\text{difference}} = 0.18$, $p = .41$). Means and standard deviations for the different experimental conditions are shown in Table 2.

This analysis also showed a main effect of condition, $F(3, 207) = 48.76$, MSE = .31, $p < .001$, $\eta^2 = .41$, with better performance in the action compared with the other three conditions.

| Condition               | Action                                                                 | Subjective States | Emotional States | Object                                                      |
|-------------------------|------------------------------------------------------------------------|-------------------|------------------|------------------------------------------------------------|
| Action                  | Lifting/hopping/kicking/jumping (both, right foot, left foot)/pushing/digging/sitting/climbing/running/clapping/shooting a ball | Itchy/bored/tired/cold/hurt | Surprised/sad/frightened/angry/happy | Ball rotating/kitchen scales moving as weights added/ironing board opened up and closed/dust pan and brush sweeping/saw in action |

TABLE 1
The Point-Light Display Sequences
Emotion, $M_{\text{difference}} = 0.31, p < .001$; subjective state, $M_{\text{difference}} = 0.237, p < .005$; object, $M_{\text{difference}} = 1.059, p < .001$). There was no difference in accuracy between the emotion- and subjective-state conditions ($M_{\text{difference}} = 0.073, p = .46$), but there were fewer errors in the emotion and subjective states compared with the object condition (respectively, $M_{\text{difference}} = 0.75, p < .001$; $M_{\text{difference}} = 0.82, p < .001$).

Importantly, there was a significant group × condition interaction, $F(6, 207) = 2.53$, MSE = .31, $p < .05$, $\eta^2 = .07$. The interaction was analyzed using post-hoc Tukey tests. These analyses revealed that for the action condition, the deaf group obtained significantly lower scores than those of the CA-matched controls ($M_{\text{difference}} = 0.40, p < .001$) and the MA-matched controls ($M_{\text{difference}} = 0.22, p < .05$). On the object condition, they were significantly less accurate than both the CA- ($M_{\text{difference}} = 0.74, p < .001$) and the MA-matched controls ($M_{\text{difference}} = 0.75, p < .001$). For the emotion condition, they were marginally less accurate than the CA-matched controls ($M_{\text{difference}} = 0.47, p = .05$), but not the MA-matched controls ($M_{\text{difference}} = 0.16, p = .51$). Finally, the deaf participants’ scores on the subjective condition did not differ from those of the CA-matched controls ($M_{\text{difference}} = 0.15, p = .48$) or the MA-matched controls ($M_{\text{difference}} = 0.07, p = .75$).

Because of the marginal difference in the emotion condition and the apparent large difference in the standard deviations between the groups, a Levene’s test (Tabachnick & Fidell, 2001) for homogeneity of variances was performed. Due to a violation in the homogeneity of variance, a correction for the degrees of freedom was applied for the four types of stimuli. Results revealed that for the action condition, deaf children’s scores were significantly lower than those of CA-matched and MA-matched children, $t(42.21) = 4.6, p < .001$, and $t(36.58) = 2.14, p < .05$, respectively. On the emotion condition, deaf children were significantly less accurate than CA-matched children, $t(42.21) = 4.6, p < .001$, but not MA-matched children, $t(30.47) = 0.74, p < .47$. Deaf children’s scores were significantly lower on the objects condition compared with CA-matched children, $t(45.84) = 3.93, p < .001$, and MA-matched children, $t(43) = 3.49, p < .001$. Finally, for the subjective states, the results revealed no significant differences between deaf children and the CA-matched or MA-matched groups, $t(43.90) = 0.77, p = .45$, and $t(45.40) = 0.30, p = .77$, respectively. Importantly, the scores for the CA-matched and MA-matched control groups did not differ across any of the conditions: action ($M_{\text{difference}} = 0.18, p = .20$), emotion ($M_{\text{difference}} = 0.31, p = .39$), subjective ($M_{\text{difference}} = 0.21, p = .56$), and object ($M_{\text{difference}} = 0.003, p = .99$).

Effect of Age on Performance Levels

To evaluate the contribution of age to accuracy across the four motion conditions, hierarchical multiple regressions were carried out separately between the deaf participants and their
MA-matched controls and between the deaf children and their CA-matched controls. Each of the motion conditions was used as a dependent variable with age and group (deaf and MA-matched/deaf and CA-matched) as the independent variables. An age × group interaction was entered as a second step into the regression. The groups were coded as deaf = 0 and CA-matched = 1 in the first regression analysis and as deaf = 0 and MA-matched = 1 in the second regression analysis. The standard regression coefficients are shown in Table 3.

The results revealed that for the deaf and CA-matched controls, only performance for action was predicted by increasing age. Performance on both the action and object conditions was predicted by group with the deaf performing comparatively poorer than the CA-matched controls across both conditions.

Importantly for the deaf children and MA-matched controls, age predicted performance in all conditions, with the children showing better performance with increasing age. Group also predicted performance for each of the conditions, except for the subjective condition. Deaf children performed more poorly than MA-matched controls across each of the other three conditions. There were also significant interactions between age and group in all but the subjective conditions, showing that age had a different pattern on performance in the deaf children compared with the MA-matched controls. Further regression analyses revealed that in the action condition, age significantly predicted performance in the MA-matched controls ($\beta = .67$, $p < .001$) and the deaf participants ($\beta = -.51$, $p < .05$). However, although in the MA-matched group, children performed better as age increased, this effect was reversed for the deaf group whereby the older children performed progressively poorer in the action condition. In the object condition, age significantly predicted performance in the MA-matched controls ($\beta = .63$, $p < .001$), but this effect was not found for the deaf children ($\beta = .27$, $p = .21$). The same pattern was shown in the emotion condition—age significantly predicted performance in the MA-matched control group ($\beta = .79$, $p < .001$), but this effect was not found for the deaf children ($\beta = -.07$, $p = .74$). Thus, age appears to have a more powerful effect upon performance in the MA-matched group compared with the deaf group. Therefore, regardless of the inclusion of a much younger-aged MA-matched control group, these children performed better than their older deaf counterparts. Thus, when controlling for intelligence, clear differences were observed across deaf and hearing children, with the deaf children performing consistently poorer on the biological motion task.

### Table 3

|                     | Deaf and chronological age | Deaf and mental age |
|---------------------|----------------------------|---------------------|
|                     | Age | Group | Age × Group | Age | Group | Age × Group |
| Action              | 0.37*** | 0.49*** | −0.09 | 0.58*** | 0.47*** | 0.93* |
| Emotion             | 0.03 | 0.25 | 0.51 | 0.43** | 0.31* | 2.02*** |
| Subjective          | 0.17 | 0.09 | 0.33 | 0.35* | 0.043 | 0.95 |
| Object              | 0.18 | 0.48*** | −0.002 | 0.43*** | 0.59*** | 1.07* |

*p < .05. **p < .01. ***p < .001.
Degree of Hearing Loss and Signing Ability

To further uncover factors implicated in successful task performance in the deaf participants, we carried out further analyses (ANOVA). The first of these showed that there was no effect of severity of hearing loss on error rate, $F(1, 23) = 0.10, p = .75$. Because research has shown that deaf children with signing family members perform as well as age- and intelligence-matched hearing children on emotion recognition and ToM tasks (Courtin, 2000; Peterson & Siegal, 1999), we compared the total numbers of correct scores obtained by the 12 deaf children who had signing family members (aged 6;9—15;8; $M_{age} = 10;3; SD = 40.8$ months), with those obtained by the 12 children without signing family members (aged 6;8—16;10; $M_{age} = 12;4; SD = 28.8$ months). This included 7 families where only the mother signed and 4 where both parents signed. Five out of the 12 families were learning British Sign Language (BSL) Level 1, and the remaining 8 had completed BSL Level 3. Only one child has nonhearing parents, and in this case, both the mother and father were profoundly deaf. The analysis failed to show any significant differences, $F(2, 23) = 0.51, p = .61$. We then compared scores for the 13 deaf children who preferred to communicate using sign language (aged 6;8—15;8; $M_{age} = 10;2; SD = 38.4$ months) with those of the 11 deaf children who preferred to communicate orally (aged 7;8—16;10; $M_{age} = 12;8; SD = 30.36$ months). Again, this comparison did not reveal any significant differences, $F(1, 23) = 0.21, p = .65$.

**DISCUSSION**

The findings from the study showed that although deaf and hearing children matched for mental and chronological age did not differ in their ability to identify subjective states from PLDs, identification of emotions, actions, and objects was significantly impaired in the deaf group. In comparison with the MA-matched control group, their performance scores on the object and action conditions were significantly lower, and in comparison with the CA-matched control group, their scores were significantly lower across the emotion, action, and object conditions. Therefore, deaf children performed more poorly across most of the experimental conditions, providing additional support that deaf children may actually view motion stimuli very differently from hearing children (e.g., Bosworth & Dobkins, 2002). Deaf children differ from hearing children in detecting visual cues for objects and actions as well as in their ability to decode subtle visual cues for emotions.

This difference in levels of performance across experimental conditions in the deaf group did not simply reflect changes in levels of difficulty across conditions. Consistent with findings from earlier studies (Hubert et al., 2007; Parron et al., 2008), our results from the hearing controls showed that children’s performance was poorest on the object condition while performance was best on the action condition. Although the deaf participants showed the same pattern, their scores were nevertheless poorer than those of controls, especially in the action condition.

Performance of the deaf children across the emotion condition was consistent with previous research showing that deaf children exhibit difficulties in emotion recognition (e.g., Dyck et al.,

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1A post-hoc power analysis using G’Power (Erdfelder, Faul, & Buchner, 1996), revealed a small- to medium-size effect (.37) using the conventions proposed by Cohen (1977). Analysis also revealed that the probability of finding this power $(1−β) = .97$. 
The deaf children showed poorer performance across the emotion condition compared with CA-matched. However, the findings fail to support our hypothesis speculating that motion may significantly enhance emotion identification ability in the deaf (e.g., Hill & Johnston, 2001). Static representations (e.g., photographs) of emotional stimuli provide relatively impoverished information about social situations. Indeed, work carried out with hearing populations has revealed increased recognition of emotions when test stimuli are dynamic (Bould & Morris, 2008), and yet, this was not observed in the deaf group.

Problems in understanding other people’s emotions (e.g., Rieffe & Terwogt, 2000) have often been interpreted in the context of lack of ToM. Findings from studies testing these mentalizing abilities in deaf participants have reported deficits (e.g., Rieffe & Terwogt), and these may provide evidence for a deficit at the social cognitive level (Tager-Flusberg & Sullivan, 2000). However, although the results revealed that the deaf children identified fewer emotions from the PLDs, no differences were found across subjective states between the deaf children and the two control groups. This double dissociation between emotions and subjective emotions may reflect deaf children’s ability to have a better understanding of their own emotions but a specific difficulty in the understanding of the emotions of others. For example, Rieffe and Terwogt found when looking at spontaneous use of mental states in explaining other people’s emotions, 6- and 10-year-old deaf children’s references to desires exceeded their hearing peers and were even found to increase with age. One interpretation of better self-awareness is that the deaf children may concentrate on the expression and understanding of their own desires to make effective use of their interaction time to ensure that others unambiguously understand their wants. Therefore, understanding one’s own emotion appears to remain intact in deaf children.

An unresolved but important question is whether the deaf children scored at a lower level across the biological motion task compared with their matched controls due to their deafness per se, such that their auditory deprivation is responsible for motion deficits through limited ability to communicate with others (e.g., Peterson & Siegal, 1995, 1998), or whether experience with sign language played a role. A limitation to the current study is that all deaf children were signers, and there were no differences between the deaf children who favored communicating orally and those who favored sign. Therefore, these results cannot be interpreted in terms of whether level of signing ability in deaf children affects the ability to decode emotional and nonemotional content. In the deaf literature, key differences have often been observed in children exposed to sign from birth (e.g., Emmorey & McCullough, 2009), but only one child in the present study was a native signer, thus preventing further conclusions to be drawn on the experience of sign. Future studies need to address both native signers and hearing signers to unravel this question.

Another important question is how the four motion conditions relate to each other. Pelphrey, Adolphs, and Morris (2004) have suggested that different aspects of social perception are subserved by different, specialized brain systems and that perception of bodily motion relies on one such specialized system. Frith and Frith (1999) have further suggested that the ability to mentalize may have evolved from a system for representing actions in the brain. For example, the mirror-neuron system (MNS) is hypothesized to be a perception–action matching system that is automatically engaged during the observation of both communicative and noncommunicative gestures and actions. In addition, areas outside the MNS such as the superior temporal sulcus are also involved in the perception of biological motion and more broadly in processing social communication (e.g., Grossman & Blake, 2002). Visual regions including the fusiform...
face area and the extrastriate body area are also recruited during the perception of gestures and actions involving the hands, arms, and face (Montgomery & Haxby, 2008).

Importantly, linguistic articulators for sign language are the same as those involved in everyday human actions, such as reaching, grasping, object manipulation, and communicative gesture. Different experiences with manual communication might then alter the nature of the neural systems that underlie action for deaf signers (Corina et al., 2007), and thus, differences in any system representing actions may lead to problems in social perception including ToM. Although problems in understanding other people’s emotions have often been attributed directly to deaf children’s lack of opportunity to converse, it is possible that this may in fact be more specific to children’s signing experience. This then implies that experience using a visual language shifts neural processing of human actions (Corina & Knapp, 2008; Knapp et al., 2008; Knapp & Corina, 2010).

Given that neural mechanisms specialized for the perception of biological activity appear to play an important role in social perception (Allison, Puce, & McCarthy, 2000; Wheaton, Pipingas, Silberstein, & Puce, 2001), studies using biological motion paradigms will be important in enabling researchers to address outstanding questions about the role of action perception in deaf individuals. Although deafness alone is thought to enhance certain aspects of an individual’s visual attention (see Bavelier, Dye, & Hauser, 2006), specifically, deafness causes an individual to allocate more attention to the visual periphery and be more sensitive to motion on the periphery; effects of competency in a visual language may also enhance some cognitive functions (Emmorey & Kosslyn, 1996).

REFERENCES

Albanese, O., De Stasio, S., Di Chiaccio, C., Fiorilli, C., & Pons, F. (2010). Emotion comprehension: The impact of nonverbal intelligence. The Journal of Genetic Psychology: Research and Theory on Human Development, 171, 101–115.

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. Trends in Cognitive Science, 4, 267–278.

Bachara, G. H., Raphael, J., & Phelan, W. J. (1980). Empathy development in deaf preadolescents. American Annals of the Deaf, 125, 38–41.

Bavelier, D., Dye, M. W., & Hauser, P. C. (2006). Do deaf individuals see better? Trends in Cognitive Science, 10, 512–518.

Bertenthal, B. I., & Pinto, J. (1994). Global processing of biological motions. Psychological Science, 5, 221–225.

Blake, R., & Shiffrar, M. (2007). Perception of human motion. Annual Review of Psychology, 58, 47–73.

Bosworth, R. G., & Dobkins, K. R. (2002). Visual field asymmetries for motion processing in deaf and hearing signers. Brain and Cognition, 49, 170–181.

Bould, E., & Morris, N. (2008). Role of motion signals in recognizing subtle facial expressions of emotion. British Journal of Psychology, 99, 167–189.

Celani, G., Battacchi, M. W., & Arcidiacono, L. (1999). The understanding of the emotional meaning of facial expressions in people with autism. Journal of Autism and Developmental Disorders, 29, 57–66.

Chouchourelou, A., Toshihiko, M., Harber, K., & Shiffrar, M. (2006). The visual analysis of emotional actions. Social Neuroscience, 1, 63–74.

Clarke, T. J., Bradshaw, M. F., Field, D. T., Hampson, S. E., & Rose, D. (2005). The perception of emotion from body movement in point-light displays of interpersonal dialogue. Perception, 34, 1171–1180.

Cohen, J. (1977). Statistical power analysis for the behavioural sciences. New York, NY: Academic Press.

Corina, D. P., Chiu, Y., Knapp, H., Greenwald, R., Jose-Robertson, L., & Braun, A. (2007). Neural correlates of human action observation in hearing and deaf subjects. Brain Research, 1152, 111–129.
Corina, D. P., & Knapp, H. P. (2008). Signed language and human action processing: Evidence for functional constraints on the human mirror-neuron system. *Annals of the New York Academy of Sciences, 1145*, 100–112.

Courtin, C. (2000). The impact of sign language on cognitive development of deaf children: The case of theories of mind. *Journal of Deaf Studies and Deaf Education, 5*, 266–276.

Custrini, R. J., & Feldman, R. S. (1989). Children’s understanding of emotional facial expressions and decoding of emotions. *Journal of Child Clinical Psychology, 18*, 336–342.

Denham, S. A., McKinley, M., Couchoud, E. A., & Holt, R. (1990). Emotional and behavioral predictors of preschool peer ratings. *Child Development, 61*, 1145–1152.

Dittrich, W. H., Troscianko, T., Lea, S. E., & Morgan, D. (1996). Perception of emotion from dynamic point-light displays represented in dance. *Perception, 25*, 727–738.

Dyck, M. J., Farrugia, C., Shochet, I. M., & Holmes-Brown, M. (2004). Emotion recognition/understanding ability in hearing or vision-impaired children: Do sounds, sights, or words make the difference? *Journal of Child Psychology and Psychiatry, 45*, 789–800.

Emmorey, K., & Kosslyn, S. M. (1996). Enhanced image generation abilities in deaf signers: A right hemisphere effect. *Brain and Cognition, 32*, 28–44.

Emmorey, K., & McCullough, S. (2009). The bimodal brain: Effects of sign language experience. *Brain and Language, 110*, 208–221.

Erdle, E., Faul, F., & Buchner, A. (1996). GPOWER: A general power analysis program. *Behavior Research Methods, Instruments, & Computers, 28*, 1–11.

Frith, C. D., & Frith, U. (1999). Interacting minds: A biological basis. *Cognitive Psychology, 286*, 1692–1695.

Grossman, E. D., & Blake, R. (2002). Brain areas active during visual perception of biological motion. *Neuron, 35*, 1167–1175.

Hill, H., & Johnston, A. (2001). Categorizing sex and identity from the biological motion of faces. *Current Biology, 11*, 880–885.

Hodapp, R. M., Burack, J. A., & Zigler, E. (Eds.). (1990). *Issues in the developmental approach to mental retardation*. New York, NY: Cambridge University Press.

Hosie, J., Gray, C., Russell, P., Scott, C., & Hunter, N. (1998). The matching of facial expressions by deaf and hearing children and their production and comprehension of emotion labels. *Motivation and Emotion, 22*, 293–313.

Hubert, B., Wicker, B., Moore, D. G., Monfardini, E., Duverger, H., Da Fonseca, D., & Deruelle, C. (2007). Brief report: Recognition of emotional and non-emotional biological motion in individuals with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 37*, 1386–1392.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception and Psychophysics, 14*, 201–211.

Knapp, H. P., Cho, H., & Corina, D. P. (2008). Perception of sign language and human actions. In M. R. de Quadros (Ed.), *TISLR 9: Theoretical Issues in Sign Language Research 9. Congreso Internacional de Aspectos Teóricos das Pesquisas nas Linguas de Sinais*. December 6 to 9, 2006 Universidade Federal de Santa Catarina Florianópolis, SC Brasil. Florianópolis: Lagoa Editora.

Knapp, H. P., & Corina, D. P. (2010). A human mirror neuron system for language: Perspectives from signed languages of the deaf. *Brain and Language, 112*, 36–43.

Kusché, C. A., Garfield, T. S., & Greenberg, M. T. (1983). The understanding of emotional and social attributions in deaf adolescents. *Journal of Clinical Child Psychology, 12*, 153–160.

Leonard, L. B. (1998). *Children with specific language impairment*. Cambridge, MA: MIT Press.

Malle, B. F. (2002). Verbs of interpersonal causality and the folk theory of mind and behavior. In M. Shibatani (Ed.), *The grammar of causation and interpersonal manipulation* (pp. 57–83). Amsterdam, The Netherlands: Benjamins.

Montgomery, K. J., & Haxby, J. V. (2008). Mirror neuron system differentially activated by facial expressions and social hand gestures: A functional magnetic resonance imaging study. *Journal of Cognitive Neuroscience, 20*, 1866–1877.

Moore, D. G. (2001). Reassessing emotion recognition performance in people with mental retardation: A review. *American Journal of Mental Retardation, 106*, 481–502.

Moore, D. G., Hobson, R., & Lee, A. (1997). Components of person perception: An investigation with autistic, non-autistic retarded and typically developing children and adolescents. *British Journal of Developmental Psychology, 15*, 401–423.
Nowicki, S., & Duke, M. P. (1992). The association of children’s nonverbal decoding abilities with their popularity, locus of control, and academic achievement. *The Journal of Genetic Psychology, 153*, 385–393.

Parron, C., Da Fonseca, D., Santos, A., Moore, D. G., Monfardini, E., & Deruelle, C. (2008). Recognition of biological motion in children with autistic spectrum disorders. *Autism, 12*, 261–274.

Pavlova, M., Kragehlof-Mann, I., Sokolov, A., & Birbaumer, N. (2001). Recognition of point-light biological motion displays by young children. *Perception, 30*, 925–933.

Pelphrey, K., Adolphs, R., & Morris, J. P. (2004). Neuroanatomical substrates of social cognition dysfunction in autism. *Mental Retardation and Developmental Disabilities Research Review, 10*, 259–271.

Peterson, C., & Siegal, M. (1995). Deafness, conversation and theory of mind. *Journal of Child Psychology and Psychiatry, 36*, 459–474.

Peterson, C., & Siegal, M. (1998). Changing focus on the representational mind: Deaf, autistic and normal hearing children’s concepts of false photos, false drawings and false beliefs. *British Journal of Developmental Psychology, 16*, 301–320.

Peterson, C., & Siegal, M. (1999). Representing inner worlds: Theory of mind in autistic, deaf, and normal hearing children. *Psychological Science, 10*, 126–129.

Peterson, C., & Slaughter, V. (2006). Telling the story of ToM: Deaf and hearing children’s narratives and false belief understanding. *British Journal of Developmental Psychology, 24*, 151–179.

Pollick, F. E., Hill, H., Calder, A., & Paterson, H. (2003). Recognizing facial expression from spatially and temporally modified movements. *Perception, 32*, 813–826.

Raven, J. C., Court, J. H., & Raven, J. (1992). *The standard progressive matrices*. Oxford, UK: Oxford University Press.

Remmel, E., & Peters, K. (2008). Theory of mind and language in children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 14*, 218–236.

Rieffe, C., & Terwogt, M. (2000). Deaf children’s understanding of emotions: Desires take precedence. *Journal of Child Psychology and Psychiatry, 41*, 601–608.

Russell, J. A., Hosie, C. D., Gray, C., Scott, C., Hunter, N., Banks, J. S., & Macaulay, M. C. (1998). The development of theory of mind in deaf children. *Journal of Child Psychology and Psychiatry, 39*, 903–910.

Schiff, W. (1973). Social-event perception and stimulus pooling in deaf and hearing observers. *American Journal of Psychology, 86*, 61–78.

Steeds, L., Rowe, K., & Dowker, A. (1997). Deaf children’s understanding of beliefs and desires. *Journal of Deaf Studies and Deaf Education, 2*, 185–195.

Tabachnick, B. G., & Fidell, L. S. (2001). *Using multivariate statistics*. London: Allyn and Bacon.

Tager-Flusberg, H., & Sullivan, K. (2000). A componential view of theory of mind: Evidence from Williams syndrome. *Cognition, 76*, 59–89.

Vernon, M., & Greenberg, S. (1999). Violence in deaf and hard-of-hearing people: A review of the literature. *Aggression and Violent Behaviour, 4*, 259–272.

Wauters, L. N., & Knoors, H. (2007). Social integration of deaf children in inclusive settings. *Journal of Deaf Studies and Deaf Education, 13*, 21–36.

Wehrle, T., Kaiser, S., Schmidt, S., & Scherer, K. R. (2000). Studying the dynamics of emotional expression using synthesized facial muscle movements. *Journal of Personality and Social Psychology, 78*, 105–119.

Weisel, A., & Bar-Lev, H. (1992). Role taking ability, nonverbal sensitivity, language and social adjustment of deaf adolescents. *Educational Psychology, 12*, 3–13.

Wheaton, K. J., Pipingas, A., Silberstein, R. B., & Puce, A. (2001). Neuronal responses elicited to viewing the actions of others. *Vision Neuroscience, 18*, 401–406.