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Adults' and Children's Identification of Faces and Emotions from Isolated Motion Cues

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ADULTS' AND CHILDREN'S IDENTIFICATION OF FACES AND EMOTIONS FROM ISOLATED MOTION CUES

By

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Under the Direction of Rebecca Williamson, PhD

ABSTRACT

Faces communicate a wealth of information, including cues to others' internal emotional states. Face processing is often studied using static stimuli; however, in real life, faces are dynamic. The current project examines face detection and emotion recognition from isolated motion cues. Across two studies, facial motion is presented in point-light displays (PLDs), in which moving white dots against a black screen correspond to dynamic regions of the face.

In Study 1, adults were asked to identify the upright facial motion of five basic emotional expressions (e.g., surprise) and five neutral non-rigid movements (e.g., yawning) versus inverted and scrambled distractors. Prior work with static stimuli finds that certain cues, including the addition of motion information, the spatial arrangement of elements, and the emotional significance of stimuli affect face detection. This study found significant effects involving each of these factors using facial PLDs. Notably, face detection was most accurate in response to face-like arrangements, and motion information was useful in response to unusual point configurations. These results suggest that similar processes underlie the processing of static face images and isolated facial motion cues.

In Study 2, children and adults were asked to match PLDs of emotional expressions to their corresponding labels (e.g., match a smiling PLD with the word "happy"). Prior work with face images finds that emotion recognition improves with age, but the developmental trajectory depends critically on the emotion to be recognized. Emotion recognition in response to PLDs improved with age, and there were different trajectories across the five emotions tested.

Overall, this dissertation contributes to the understanding of the influence of motion information in face processing and emotion recognition, by demonstrating that there are similarities in how people process full-featured static faces and isolated facial motion cues in PLDs (which lack features). The finding that even young children can detect emotions from isolated facial motion indicates that features are not needed for making these types of social judgments. PLD stimuli hold promise for future interventions with atypically developing populations.

INDEX WORDS: Face processing, Emotion recognition, Point-light displays, Motion, Cognitive development, Social cognition

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1 INTRODUCTION

Interpreting faces is essential for navigating human life. For one, faces provide information regarding identity, which we use to assess whether to approach, avoid, help, or harm another person. In addition, faces help us understand others. For example, from the direction of eye gaze alone we can readily infer another's desires and beliefs (Emery, 2000). Cross-cultural research also suggests that humans possess a common ability to perceive emotions from facial expressions alone, independent of exposure to media that depicts prototypical emotional expressions (Ekman, Sorensen, & Friesen, 1969). Information from faces also enhances understanding of spoken communication (Rosenblum, Johnson, & Saldaña, 1996). In fact, we are so attuned to faces that we perceive them even when they are not there, in chance arrangements of non-face objects (e.g., seeing a face in the clouds; Liu, Li, Feng, Li, Tian, & Lee, 2014).

Given the high importance of faces, it makes sense that a large amount of research is dedicated to understanding human face perception. Research on the development of this ability reveals that even very young infants are attuned to faces. For example, one study found that infants as young as three months old preferentially attend to faces versus other elements within an animated video, and that this tendency increases with age (Frank, Vul, & Johnson, 2009). In addition, research finds that newborn infants are able to discriminate individual faces (e.g., Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002) and prefer to look at attractive faces (e.g., Langlois, Roggman, Casey, Ritter, Rieser-Danner, Jenkins, & Vivian, 1987). These rudimentary abilities develop into expert-level face recognition in adulthood (Pascalis, et al., 2011). Fully-developed 'face expertise' is evidenced by adults' ability to identify a familiar face in about 0.5 seconds, and store countless faces in memory despite a high level of similarity among items (see Carey, 1992, for review).

It is important to note that most research on face processing has used static stimuli. This is in contrast to real life experience, where faces are dynamic. Research using the "still face" paradigm has revealed that online shared interactions with moving faces are critical for infants' social development (Adamson & Frick, 2003). In addition, familiar faces encountered in real life are accompanied by unique cues, including speech and characteristic patterns of motion (Guellai, Coulon, & Streri, 2011; O'Toole, Roark, & Abdi, 2002; Spencer, O'Brien, Johnston, & Hill, 2006). However, relatively few studies have isolated motion information to investigate how it contributes to face processing abilities.

Motion cues, including biological and human motion, can be isolated through use of point-light displays (PLDs). In these displays, moving white dots against a black screen correspond to major joints (in the case of full body displays) or specific body parts (for example, the chin). Johansson (1973) pioneered the PLD technique with full bodies by attaching reflective tape to the major joints of an actor, and then altering the illumination such that the reflective tape appeared in bright contrast to a dark background. This spurred a long line of research using full-body PLDs, which finds that adults can readily identify a wealth of information from them. This includes the type of action being executed (Dittrich, 1993), an actor's gender (Kozlowski & Cutting, 1977; Mather & Murdoch, 1994), and their emotional state (Alaerts, Nackaerts, Meyns, Swinnen, & Wenderoth, 2011). Even infants appear to be sensitive to biological motion. For example, one study found that infants prefer to look at an upright PLD of a walking chicken versus random motion or an inverted distractor (Simion, Regolin, & Bulf, 2008).

Bassili (1978) was the first to apply the point-light display technique to faces, by marking white dots on an actor's face and reducing illumination such that only the dots were visible against a dark background. Research with facial PLDs suggests that face and emotion recognition from isolated motion cues reaches near-ceiling levels in adulthood. Bassili (1978) found that adults spontaneously characterize a facial PLD as being a face, and could also match emotion word labels to corresponding dynamic facial PLDs at above-chance levels. In addition, Doi and colleagues (2008) found that adults can reliably match four different dynamic facial PLDs (happiness, surprise, anger, and eyes closing) to their corresponding face caricatures (Doi, Kato, Hashimoto, & Masataka, 2008). However, these studies used a high number of points in the displays (80-100), which may have outlined face features and made featural information apparent. The current work tests face detection and emotion recognition from PLDs that contain considerably fewer points (22).

There is also limited evidence that infants and children can make sense of facial PLDs. One study examined 7- and 8-month-olds' neural responses to facial PLDs using near-infrared spectroscopy, which revealed increased activity in right-lateralized temporal areas (hypothesized to be specific to face processing) in response to upright, but not inverted displays (Ichikawa, Kanazawa, Yamaguchi, & Kakigi, 2010). In addition, 4- to 8-month-old infants are able to discriminate individuals' speech patterns based on isolated facial motion cues (Spencer, O'Brien, Johnston, & Hill, 2006). These findings demonstrate an early-developing sensitivity to isolated facial motion. However, young children's explicit understanding of facial PLDs remains equivocal. The aforementioned study by Doi and colleagues (2008) examined emotion recognition from facial PLDs in 4- to 6-year-old children using a matching task, and found that all ages could only reliably match a smiling PLD to a picture of a smiling face (Doi, et al., 2008). The younger group (4-year-olds) matched a surprised PLD correctly, and the older group (5- and 6-year-olds) correctly matched eyes closing. More research is needed to fully understand the development of face and emotion recognition from PLDs. The current project contributes to this area of investigation by examining these abilities in children and adults, with the overall aim of determining the importance of motion information in face processing.

1.1 The Current Study

My dissertation uses facial PLDs to examine the role of motion in adults' and children's face processing. In Study 1, I investigate three key questions that have not been systematically explored in previous research using facial PLDs. Specifically, I test whether a) motion is beneficial in interpreting PLDs, b) face detection accuracy depends on the arrangement of points, and c) accuracy depends on the emotional significance of motion displayed in the PLDs. The variations in point arrangement were designed to disrupt the visual cues that are hypothesized to guide infants' attention towards faces (top-heavy asymmetry and bilateral symmetry; see below). In addition, past work with face images suggests that emotionally valenced stimuli capture attention in search tasks (see Vuilleumier, 2005, for review); comparisons of responses to emotional and neutral stimuli in Study 1 elucidate whether emotional significance also aids face detection from PLDs.

In Study 2, I examine whether adults and children can recognize basic emotions from isolated facial motion, which builds on prior work examining the development of emotion recognition from static faces (e.g., Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Herba, Landau, Russell, Ecker, & Phillips, 2006) and full-body motion displays (e.g., Alaerts, et al., 2011; Ross, Poulson, & Grosbas, 2012). To assess whether motion information is beneficial for recognizing emotions from PLDs, I compare adults' responses to both static and dynamic displays. Differences in response accuracies may highlight a general benefit of motion information, and clarify whether recognition of certain emotions is better aided by motion information than others. Children were tested on dynamic PLDs to assess the development of emotion recognition in response to isolated facial motion. Prior work with face images finds that emotion recognition generally improves with age (Herba, et al., 2006), and that the developmental trajectory depends on the emotion to be recognized (Durand, et al., 2007). Study 2 determines if these patterns also hold in response to facial PLDs.

Taken together, the results from these studies clarify whether isolated motion allows for face detection (and which cues promote this ability; Study 1) and aids emotion recognition from PLDs (Study 2), and will also chart developmental patterns of emotion recognition in response to isolated facial motion information (Study 2). This work broadly contributes to the understanding of how facial motion influences face processing, and its role in the development of emotion recognition.

1.2 Developmental Considerations for Studies of Facial Motion Processing

The foundations for specialized face perception appear to be present from birth; however, the exact features of these innate components remain unclear. Some argue that a full representation of a face is innately programmed, which leads infants to seek out faces in their visual environment (e.g., Morton & Johnson, 1991). Others posit that domain-general perceptual biases can account for these findings (e.g., Simion, Valenza, Macchi Cassia, Turati, & Umilta, 2002). These hypotheses rely on data from preferential looking and orienting paradigms. In preferential looking studies, infants are presented with stimuli on the left and right sides of the visual field, and their preference for looking at one stimulus versus the other is measured. Similarly, in orienting studies, infants are presented with a stimulus in the center of the visual field, and their turning towards the stimulus as it moves to the left or right is measured. Studies using these methods have demonstrated that neonates track and attend to faces and face-like configurations from birth (e.g., Farroni, et al., 2005).

Some researchers posit that general perceptual biases explain neonates' visual preference for faces. General preferences for face-like configurations (e.g., top-heavy asymmetric patterns; see below) lead infants to seek out faces, and later become attuned to faces only. In line with this proposal, Simion and colleagues have demonstrated across several studies that neonates show a visual preference for geometric patterns that approximate a human face, but are not actually faces, over other complex patterns (see Simion, Macchi Cassia, Turati, & Valenza, 2003, for review). These data are used to explain the results of one of the first experiments documenting newborn infants' preferential orienting towards black and white face caricatures (Goren, Sarty, & Wu, 1975). In this classic study, infants reliably oriented towards face-like arrangements of the black sketched features, versus displays with scrambled features, or no features; this aligns with a preference for certain geometric arrangements rather than faces per se.

Johnson and colleagues replicated the findings by Goren, et al. (1975), but also found that eye and mouth features in a face-like arrangement were tracked more reliably than identically configured black squares (Experiments 1 and 2; Johnson, Dziurawiec, Ellis, & Morton, 1991). More recent studies have also shown that infants respond to naturalistic face stimuli, as evidenced by preferential orienting towards upright face photographs (Farroni, et al., 2005) and improved recognition of faces presented in dynamic video displays (Otsuka, et al., 2009). From these results, it is not clear that the neonatal visual preference for faces can be explained by more general mechanisms.

The above-referenced work suggests that specific visual cues guide infants' attention to faces and face-like stimuli. One such feature relates to the spatial arrangement of features within an oval boundary, which has been examined across several studies. Preferential looking paradigms have revealed that infants prefer to look at top-heavy up-down asymmetric patterns, for example, one with two elements in the top half and one in the bottom half (see Figure 1 for examples; Simion, Macchi Cassia, Turati, & Valenza, 2003 for review). In their chapter, Simion and colleagues argue that the newborns' face preference reflects a domain-general attuning towards top-heavy up-down asymmetric displays, which becomes attuned specifically to faces with experience. This suggests that top-heavy up-down asymmetry is a salient cue for detecting faces from early in development. Research also finds that infants show a novelty preference for asymmetric faces, which is taken to indicate that they find these faces unusual (Rhodes, Geddes, Jeffry, Dziurawiec, & Clark, 2002). Thus, disrupting top-heavy asymmetry or bilateral symmetry may make face detection more difficult.

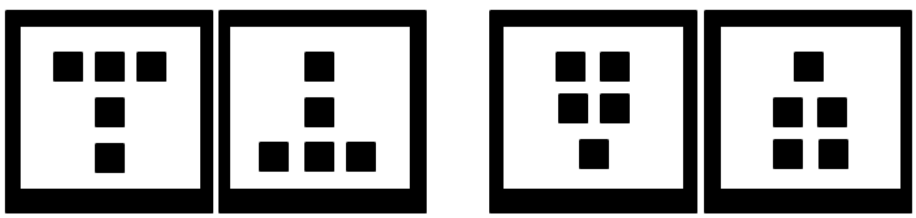

Figure 1. Example stimuli pairs used to test infants' visual preference for top-heavy up-down asymmetric patterns (left in each pair) versus bottom-heavy ones (right).

Regardless of the exact mechanism, these studies show that from early in development, humans readily attend to faces. Further, there is evidence that early experiences shape later face processing. In studies of individual recognition, young infants show a visual preference for the gender of their primary caregiver (Quinn, et al., 2002). For example, in Experiment 5 of this study, infants who had been primarily raised by fathers showed a spontaneous familiarity preference for male faces over females. In addition, infants show individual variation in their ability to recognize familiar individuals, based on their experiences. Specifically, research suggests that infants undergo a period of "perceptual narrowing" between six and nine months of age, during which they become specialized in recognizing and distinguishing faces of ownspecies individuals (versus monkey faces; Pascalis, de Haan, & Nelson, 2002) and own-race individuals (Kelly, et al., 2007). These studies show that early experiences affect face processing.

These types of visual biases in infancy lead to differences in explicit recognition ability in childhood and adulthood. Dubbed the “own-race bias” (ORB), children as young as 3 years old are shown to be more accurate in recognizing own-race individuals than those of another race (e.g., Pezdek, Blandon-Gitlin, & Moore, 2003). In this study, white children were more accurate in recognizing familiar white faces than black faces; the opposite was true for black children. In another experiment testing recognition of Asian faces, Caucasian children between 6 and 14 years old showed the expected ORB, whereas Asian children adopted into Caucasian families did not (de Heering, de Liedekerke, Deboni, & Rossion, 2010). Several studies have demonstrated the ORB across adult populations (e.g., Meissner & Brigham, 2001; Meissner, Brigham, & Butz, 2005); despite adults’ ‘face expertise’, they are not uniformly capable of recognizing all faces. Some studies find that that high contact with other-race individuals improves recognition (e.g., Chioro & Valentine, 1995).

Taken together, the developmental literature indicates that even infants easily recognize face images and face-like patterns, and that they actively seek them out in their visual environment. Adults and children are adept at finding faces; even when degraded displays (e.g., PLDs) are used, it is possible that individuals can detect faces from featural (static) information, and motion is not needed. Thus, a challenge for studies of facial motion processing lies in determining how to isolate motion. In Study 1, this issue regarding what types of information can be gleaned from static information alone is addressed by comparing adults’ responses to both static and dynamic PLDs. Responses to static displays provide a baseline of what participants can glean from motionless facial PLDs; responses to dynamic displays clarify whether motion helps adults detect faces from PLDs. Further, the research assessing infants' visual preferences may provide suggestions for how to prevent face detection from static information alone. In Study 1, point arrangements are varied across three conditions in ways that, according to neonatal studies, may obscure the presence of a face. By comparing responses across static and dynamic PLDs in three distinct point arrangements, this project assesses the role of motion in face processing from degraded displays.

Although the first study includes only adult participants, it represents an initial step in understanding face processing from PLDs that could later be extended to young children and infants. Comparisons across development could elucidate the mechanisms that commonly promote and shape face processing in response to both full-featured face images and isolated facial motion cues.

1.3 Role of Emotion in Face Processing

Face processing is not only affected by trait information, such as an individual's gender or race; it can also be affected by transient facial information, such as the presence of an emotional expression. Several studies have found that stimuli holding emotional significance are more easily detected than neutral stimuli (see Vuilleumier, 2005, for review). In addition, research shows that these differences are not due to variation in features alone, since detection of emotional faces is not faster when stimuli are inverted (Eastwood, Smilek, & Merikle, 2001). Others have suggested that emotional information "pops out" and is processed automatically (e.g., Batty & Taylor, 2003; White, 1995).

In Study 1, responses to emotional stimuli (PLDs created from facial expressions of emotion) and neutral stimuli (PLDs created from neutral non-rigid facial actions) were collected. A comparison of responses across stimuli types assesses the possibility that the presence of emotional information in the PLDs guides participants' attention to the location of a face, and improves performance in a face detection task using PLDs. Based on the aforementioned work demonstrating that emotional stimuli are processed more easily, I expect higher response accuracies to emotional stimuli, which would suggest that emotional significance of stimuli aids face detection from PLDs. However, given that adults are face experts, it is possible that they are highly accurate in detecting faces across both stimuli sets in these studies.

1.4 Development of Emotion Recognition

Emotion recognition is a critical aspect of social interaction and communication, as it allows us to quickly and easily interpret how others are feeling (Batty & Taylor, 2003). Six emotional expressions (anger, fear, joy, surprise, disgust, and sadness) are posited to be similarly expressed and understood across cultures (Ekman & Friesen, 1971) and research finds that even infants can discriminate between these 'basic' emotions (see Walker-Andrews, 1997, for review). In one experiment, Schwartz and colleagues (1985) found that 5-month-old infants could discriminate between anger, fear, and sadness; however, in a second experiment, infants of the same age failed to discriminate between anger, joy, and interest (Schwartz, Izard, & Ansul, 1985). Still, the ability to discriminate does not necessarily confirm infants' true understanding of emotion.

Research with older infants provides clearer evidence of emotion recognition. For example, one study found that 7-month-olds are sensitive to cross-modal matching of emotions between facial expression and vocal tone (Soken & Pick, 1992). Another study found that 7-month-olds could recognize the similarity of different portrayals of happiness versus portrayals of fear and anger (Kestenbaum & Nelson, 1990). These studies suggest that older infants are able to generalize their interpretations of emotional stimuli. At 12 months of age, infants use information from facial expressions of emotion to guide their behaviors, for example, in deciding whether to approach an object (e.g., Sorce, Emde, Campos, & Klinnert, 1985).

Some research suggests that featural information, especially from the eyes, is important for interpreting others' emotional states (e.g., Baron-Cohen, Wheelwright, Raste, & Plumb, 2001; Sullivan, Ruffman, & Hutton, 2007). Most research on emotion recognition and its development have used static stimuli that include features. Research shows that emotion recognition improves with age when featural information is present (e.g., Bruce, et al., 2000; Herba, et al., 2006), but even preschool-age children can identify emotions conveyed by photographs of facial expressions at above-chance levels (e.g., Bullock & Russell, 1985; Camras & Allison, 1985; Widen & Russell, 2003).

In addition, it appears that recognition of certain emotions develops more quickly than others. In particular, happiness is one of the first emotions that children can recognize; even preschool-age children can label faces as "happy" at adult levels of accuracy (e.g., Camras & Allison, 1985; Durand, et al., 2007). In one study (Durand, et al., 2007), recognition of happiness and sadness reached adult levels of accuracy by children as young as 5 years old. In contrast, recognition of fear reached adult levels at 7 years of age, and anger appeared to develop around age 9. The delayed understanding of fear and anger is further supported by a study showing that older children (ages 7-13) and adolescents (age 14-18) are less sensitive to facial expressions of anger and fear compared to adults (Thomas, DeBellis, Graham, & LaBar, 2007). Thus, the developmental trajectory for accurate emotion recognition, from static displays that include featural information, depends on the emotion to be recognized.

1.4.1 Recognizing Emotions from Bodily Motion

There is considerably less research examining the role of motion information in recognizing emotions. A handful of studies have examined emotion recognition from isolated motion in full-body PLDs. For example, one study found that adults were capable recognizing emotions from PLDs of full-body movements (e.g., jumping up and down), by indicating whether the emotion expressed in a 'target' PLD movie was happier, sadder, angrier, or not different when compared to a neutral PLD movie (Alaerts, et al., 2011). The development of emotion recognition has also been investigated using full-body PLDs. Ross, et al. (2012) asked children between ages 4 and 17 to label full-body PLDs (captured from actors' interpretations of spontaneously feeling four emotions) as 'happy', 'sad', 'scared', or 'angry'. They found that emotion recognition from full-body PLDs reached adult levels at around age 8. In contrast to research using static images of facial emotional expressions (see above), there were no significant differences in response accuracy by emotion type.

1.4.2 Recognizing Emotions from Facial Motion

Ekman and Friesen (1976) pioneered the concept of identifying emotions from small facial muscle movements using their Facial Action Coding System (FACS). In their system, expressions are categorized by the smallest noticeable movements in specific facial muscles, or as they are called in the manual, action units. FACS has been widely recognized as the premier method for coding facial movements and has been adapted for machine learning purposes (e.g., Bartlett, et al., 2005; Essa & Pentland, 1997). Ekman and Friesen (1976) originally reported that it takes about 40 hours to learn FACS coding, but today there are five-day workshops available for those wishing to learn the coding system (one website estimates that self-instruction through the FACS manual takes about 100 hours to complete).

While mastering FACS can be useful for certain applications, such as learning to detect fleeting micro-expressions, research suggests that adults are capable of recognizing emotions from motion without explicit training. Bassili (1979) followed up his initial study using the point-light technique with faces by asking another group of adults to match dynamic facial PLDs with corresponding emotion labels; across each of the six basic emotions (anger, fear, joy, surprise, sadness, and disgust), adults correctly labeled the PLDs at above-chance levels.

A similar experiment with 4- to 6-year-old children and adults found that all children could reliably match a happy face caricature with a smiling facial PLD (Doi, et al., 2008). However, results were mixed for ‘eyes closing’ displays (which only 4-year-olds matched above chance) and for “surprised” displays (which only 5- and 6-year-olds matched accurately). None of the child groups matched the ‘angry’ PLD and face caricature above chance levels. Adults, in contrast, were able to match all four PLD expressions (happy, surprised, angry, and eyes closing) with the appropriate static image. These results highlight developmental differences in emotion recognition from PLDs. Study 2 of my dissertation expands on these findings by charting emotion recognition accuracy in response to dynamic facial PLDs of four basic emotions across a wider age range (3-8 years).

1.5 Summary

The reviewed literature suggests that even infants pay attention to upright biological motion (Simion, et al., 2008) and isolated facial motion cues (Ichikawa, et al., 2010; Spencer, et al., 2008). There is also limited evidence that children can make sense of biological motion cues, based on research showing that children can sometimes identify the emotions expressed in full-body PLDs (Ross, et al., 2012) and faces (Doi, et al., 2010). Comparisons of children’s performance with that of adults’ suggest substantial development from early childhood to adulthood. Several studies have demonstrated that adults can identify a large amount of information (e.g., emotional state, gender, and act executed) from isolated point-light information of full bodies (Alaerts, et al., 2011; Dittrich, 1993; Kozlowski & Cutting, 1977; Mather & Murdoch, 1994) and faces (Bassili, 1978, 1979; Doi, et al., 2010).

The current project investigates the role of motion information in face detection and emotion recognition, and extends past work by considering which other visual cues might influence these abilities (e.g., point arrangement and emotional salience; Study 1). Differences in adults' response patterns may highlight how face processing in response to isolated motion displays varies based on these factors. The development of emotion recognition in response isolated facial motion cues is also assessed across a wider age range than has been previously studied (ages 3-8, Study 2). Specifically, developmental comparisons in Study 2 may clarify whether emotion recognition from PLDs follows a similar developmental trajectory to what is found with static displays. Taking together results from both studies, this project elucidates the role of motion information in face detection abilities in adulthood and emotion recognition across development.

2 STUDY 1

2.1 Method

2.1.1 Face Detection from Isolated Motion

The goal of Study 1 is to examine face detection in response to isolated facial motion cues, which were presented in PLDs. I examine whether or not adults can identify upright faces from PLDs, by presenting upright PLDs against inverted and scrambled distractor displays in a forced-choice procedure. These displays were created by tracking facial movements generated by the production of five basic emotional expressions and five neutral facial actions involving non-rigid movements. Adults were presented with two concurrent PLDs and asked to indicate which one looked like a face. This method allows for direct examination of face processing in response to limited point-light information, with a baseline criterion of 50% chance accuracy.

Several studies of face processing have demonstrated that the spatial arrangement of face features in their upright configuration is critically important to human face processing, and that face processing is disrupted when faces are presented upside-down (dubbed the "facial inversion effect"; see Tanaka & Gordon, 2011, for review). In a standard old-new recognition task, inverting a previously-seen face upside down during test trials significantly lowers recognition accuracy (e.g., Yin 1969; Diamond & Carey 1986), and the magnitude of the inversion effect appears to be unique to faces (e.g., Rossion & Curran, 2010. The current study makes use of the facial inversion effect by using inverted PLDs as distractor items (presented alongside upright PLDs). These stimuli are ideal for this study because they control for point arrangement, total point movement, and local motion patterns. In addition, use of inverted facial PLDs can assess whether adult subjects identify upside-down faces as faces, or if face detection is specific to upright stimuli. Scrambled stimuli are also used, which is consistent with past studies of adults' responses to biological motion of full bodies (Troje & Westhoff, 2006).

A primary consideration of the current study is whether or not motion information is necessary or beneficial for detecting faces from PLDs. To address this question, adults will be presented with either dynamic PLD videos or static images taken from the PLDs at their maximum expression. A between-subjects comparison of responses in the static and dynamic conditions will determine whether motion is needed to correctly interpret the limited information in PLDs, or if the information available from the arrangement of the points is sufficient to detect a face. The latter possibility would provide further support for accounts of fully developed face-expertise in adulthood (e.g., Carey, 1992), although a benefit of motion is expected based on prior work examining face detection from PLDs (Bassili, 1978) and other work using static and dynamic PLDs of full bodies (Atkinson, Dittrich, Gemmell, & Young, 2004).

A second consideration is whether or not the arrangement of points plays an important role in face detection from PLDs. Past work examining infants' attentional biases to faces and face-like patterns suggests that certain visual configurations or cues are important in face perception. Specifically, certain geometric features of faces capture infant attention; thus, disrupting the presence of these cues in PLDs might make a face harder to detect.

Study 1 of my dissertation uses PLDs of faces, with different arrangements of 22 points per display across three conditions. In two conditions, the points are arranged in a way that is not "face-like", based on findings from research with infants; specifically, I systematically disrupt top-heavy up-down asymmetry and bilateral symmetry in two conditions, and will compare responses to these stimuli to a condition where these visual features are preserved. These between-subjects comparisons determine whether the visual cues that guide infant face perception are also important for identifying faces from isolated motion information.

In the “schematic” condition, the white dots in the images and PLDs are arranged to outline the eyes and mouth, creating an approximation of a face with two elements in the top and one element in the bottom. In the “bottom-heavy” condition, the points within the facial PLDs will be arranged in such a way that there are a greater number of dots in the bottom half (i.e., bottom-heavy up-down asymmetry). In the “bilaterally asymmetric” condition, there are a greater number of points on one side. Example stimuli from these three conditions are shown in Figure 2. The total number of points is controlled for across conditions, with 22 per display.

Figure 2. Example point-light displays in schematic (left), bottom-heavy (center), and bilaterally asymmetric (right) configurations.

An interaction between presentation mode (static or dynamic) and point arrangement may reveal that motion is needed to detect faces, but only in certain PLD point arrangements. Pilot data suggests that adults can correctly interpret schematic PLDs even without motion information; this preliminary result speaks to a focal issue in research examining facial motion, which is that static information is usually quite sufficient to make judgments about faces. Other researchers have circumvented this issue in order to study facial motion by degrading static displays of faces such that they are less easily recognized, for example, by presenting thresholded gray-scale images (Lander & Bruce, 2000) or negatives (Knight & Johnston, 1997). I posit that the two ‘disrupted’ point arrangements are key candidates for illustrating the benefit of motion information in making sense of facial PLDs. This exploration in the importance of point arrangement could also provide a benchmark for future work using PLDs.

Lastly, prior work with face images suggests that emotional stimuli, in comparison to neutral stimuli, capture and guide attention (Vuilleumier, 2005). To assess whether this is true in tasks using isolated facial motion, adults will be presented with both emotional PLDs (generated from an actor's production of five facial expressions of emotion, such as a joyful smile) and neutral PLDs (generated from an actor's production of neutral non-rigid acts, such as chewing). Within-subjects comparisons of responses to these two stimuli types determine whether emotional significance of stimuli aids face detection from PLDs.

2.1.2 Participants

Adults (*n* = 96; range 18-46 years, *M* = 20.92, *SD* = 4.89; 20 males) were recruited from the Georgia State University undergraduate research participants pool. In this sample, 33.33% of participants identified as Black/African American, 27.08% as Asian, 19.79% as White, 13.54% as mixed race, 1.04% as American Indian/Alaska Native, and 1.04% did not specify. This sample is taken to reflect the diversity of the Atlanta area and the undergraduate population at GSU.

2.1.3 Materials

Full-body videos for the practice trials were found online and marked as available for research use by Creative Commons. PLDs for the practice trials were taken from an online research database available at http://astro.temple.edu/~tshipley/mocap/dotMovie.html.

To make the PLD videos, dots were drawn on an actor's face with makeup. Starting at a neutral expression, her expressions of five emotions (anger, fear, joy, sadness, and surprise) and five neutral non-rigid actions (blinking, blowing, chewing, talking, and yawning) were recorded. Disgust, the final of the six basic emotions, seems to be particularly difficult for adults to recognize (Widen & Russell, 2008). For this reason, disgust was excluded from the set of emotional PLDs.

Using Adobe After Effects CS 5.5 software, the motion of each dot was tracked and made to look like 22 white points moving against a black screen. This novel technique produces stimuli comparable to traditional PLDs made with reflective points. The resulting displays were designed to include considerably fewer points (22 per display) than have been used in past investigations (ranging 80-100; Bassili, 1978, 1979; Doi, et al., 2008). The configuration of the dots shown within each video varied by condition (see above). Each video ranged from 3-4 seconds in length. Images for the static condition were created by taking screenshots of the PLDs at the point of maximum expression.

For each facial expression and movement, inverted and scrambled distractor displays were also created. The inverted displays were created by rotating the upright PLDs 180° on their horizontal axes. The scrambled PLDs were created by changing the starting location of each point. Specifically, the upright PLDs were divided into quadrants, and each point was moved to a starting location of another point within the same quadrant. By this method, the starting and ending configuration of both the upright and scrambled displays remained the same (i.e., the points are arranged nearly identically when the face is at a neutral expression), but the motion patterns of the scrambled displays were misaligned. This method keeps local motion patterns intact and is consistent with past studies (e.g., Grossman & Blake, 2002). An example comparison of upright and scrambled PLD motion patterns is shown in Figure 3. In line with past comparisons in face perception and biological motion literature (e.g., O'Brien, Spencer, Girges, Johnston, & Hill, 2014; Troje & Westhoff, 2006), these distractor stimuli control for the total amount of motion among the points, and, in the case of the inverted displays, the points' arrangement.

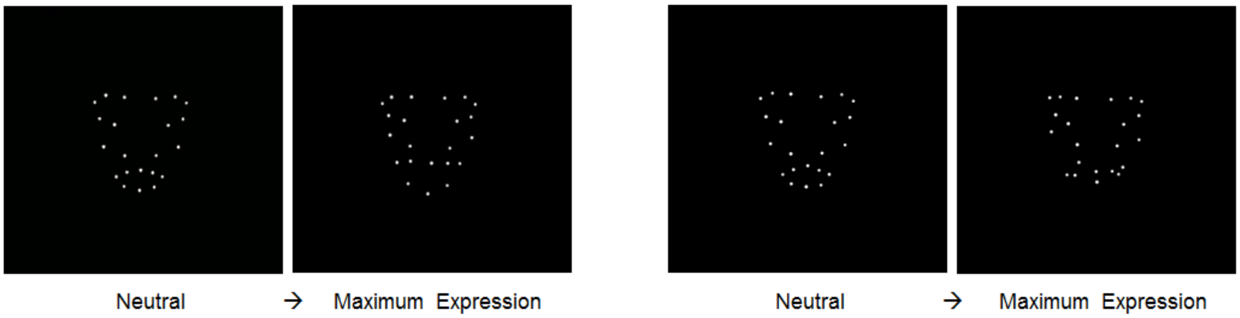

Figure 3. Contrast of motion patterns between upright (left) and scrambled (right) schematic PLDs.

All studies for this dissertation were implemented using E-Prime 2.0 on a laptop computer. The PLD videos were played together on a single slide, side-by-side in a continuous loop to equate for total presentation length.

2.1.4 Procedure

Participants were tested individually in a lab room and moved through the experiment independently by following the displayed prompts. This study utilized a two-alternative forced choice (2AFC) format, in which pairs of stimuli (correct and incorrect answers) were presented on the left and right sides of the screen.

Practice Trials. Participants first completed two practice trials, which familiarized them with the 2AFC format of the task and PLDs in general. In the first practice trial, participants were presented with a video of a woman doing jumping jacks (see Figure 4). This first slide read "Look! It's jumping jacks!" and participants were prompted to move to the next slide by pressing the mouse. On the next slide, two full-body PLDs were presented side by side (one of jumping jacks and one of cartwheels). Adults were prompted to indicate which video looked like jumping jacks by pressing the key corresponding to their choice ('F" for the video on the left side of the screen, “J” for the video on the right side). The second practice trial was presented in the same format. Participants viewed a video of a dog walking, and were then presented with two side-by-side PLDs, one of a bat flying and one of a dog walking. Participants were asked to choose which one looks like a dog by pressing either the “F” or “J” key.

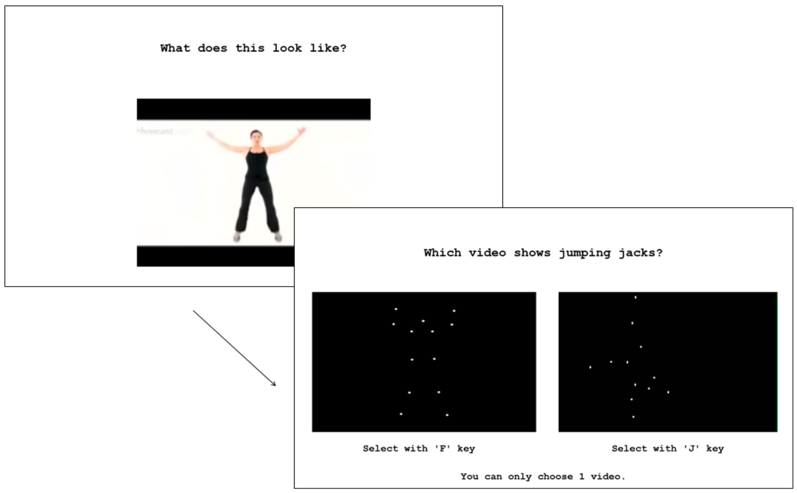

Figure 4. Example practice trial (jumping jacks).

Test Trials. Participants completed 20 test trials in which they were asked to choose which of two displays looks like a face (see Figure 5). Each participant viewed each of the 10 facial expressions and movements twice, once with an inverted distractor and once with a scrambled distractor. Across conditions, an upright PLD was always presented with the inverted or scrambled PLD of the same expression/movement, to control for local motion patterns within each stimuli pair. The PLDs played on continuous loop until a video was selected. Participants were not given any feedback regarding the accuracy of their responses. In the static condition, these PLDs were each images of the same emotion at maximum expression.

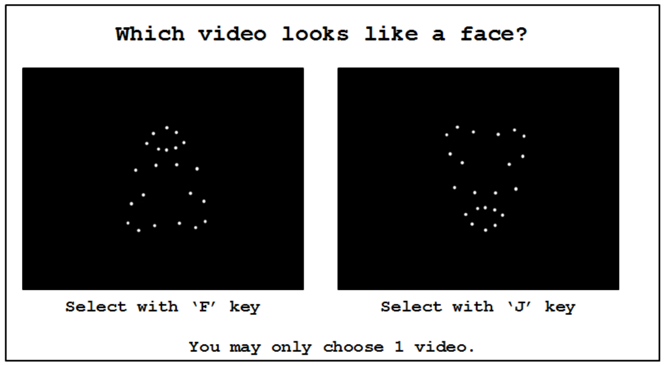

Figure 5. Example face detection trial (inverted versus upright).

2.1.5 Design

This study utilized a 2 (stimuli type; emotion or neutral) x 2 (presentation mode; static or dynamic) x 3 (point configuration; schematic, bottom-heavy, or bilaterally asymmetric) repeated measures design with 16 participants per group. The location of the upright face PLD (correct response; left or right side) was counterbalanced across trials. The presentation order of stimuli pairs was randomized.

2.2 Results

2.2.1 Scoring

Each participant's responses were recorded as correct/incorrect (1/0) in E-Prime. Response accuracies were then converted to percentages.

2.2.2 Preliminary Analyses

A preliminary analysis revealed no significant gender differences in overall accuracy, $t(94) = 0.55$, $p = .585$. Responses from both genders in each condition were combined for the main analyses. Levene's tests revealed that the assumption of homogeneity of variances was met for the emotional stimuli, $F(5, 90) = 1.82$, $p = .116$, and for neutral stimuli, $F(5, 90) = 1.82$, $p = .089$. However, Shapiro-Wilk tests revealed significant deviations from normality (p's $\leq .001$).

Use of ANOVA has been shown to be robust despite deviations from normality (e.g., Glass, Peckham, & Sanders, 1992), and nonparametric tests revealed the same findings as the parametric analyses reported here (see Appendix).

2.2.3 Main Analyses

Response accuracies were analyzed using a 2 (presentation mode; static or dynamic) x 3 (point arrangement; schematic, bottom-heavy, or bilaterally asymmetric) x 2 (stimuli type; emotion or neutral) repeated-measures ANOVA. These results are shown in Figure 6.

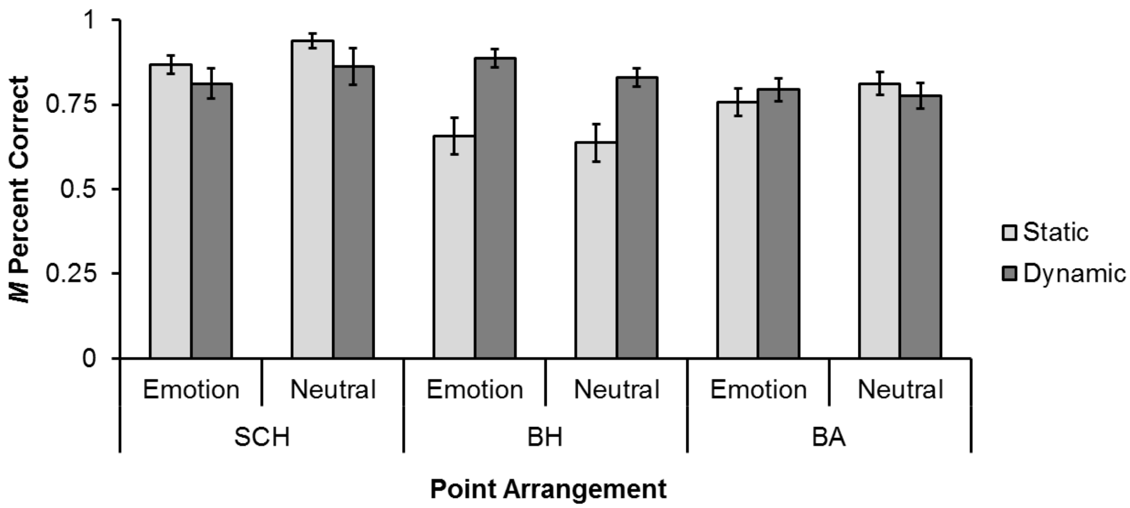

Figure 6. Average response accuracies (+/- SE) separated by stimuli type, point arrangement, and presentation mode. SCH = schematic, BH = bottom-heavy, BA = bilaterally asymmetric.

The first significant finding in this analysis clarifies whether or not there is a benefit of motion in interpreting the PLDs. Although there was no significant main effect of presentation mode, $F(1, 90) = 2.93$, $p = .090$, $\eta_p^2 = .032$, this analysis revealed a significant interaction between point arrangement and presentation mode, $F(2, 90) = 8.62$, $p \leq .001$, $\eta_p^2 = .161$. Follow-up analyses of simple main effects revealed that participants more accurately detected faces in response to dynamic displays (M = 85.94% correct, SD = 8.98) versus static displays (M = 64.69%, SD = 19.19) in the bottom-heavy condition, $F(1, 90) = 18.42$, $p \leq .001$. However, this simple main effect of presentation mode was not significant in either of the two other point arrangement conditions.

The second significant finding addresses the research goal of determining whether point arrangement is an important factor in interpreting PLDs. The main analysis revealed a significant main effect of point condition, $F(2, 90) = 6.01$, $p = .004$, $\eta_p^2 = .118$. Post-hoc pairwise comparisons revealed that, across stimuli types and presentation modes, participants were more accurate in the schematic condition ($M = 87.03\%$ correct, $SD = 14.75$) when compared to both the bottom-heavy condition ($M = 75.31\%$, $SD = 18.27$; Bonferroni-corrected $p = .004$) and the bilaterally asymmetric condition ($M = 78.44\%$, $SD = 12.08$; $p = .048$).

Comparisons between responses to emotional and neutral stimuli were conducted to determine whether emotional salience of stimuli aided face detection from PLDs. This within-subjects analysis revealed no main effect of stimuli type, $F(1, 90) = 0.78$, $p = .381$, $\eta_p^2 = .009$, but there was a significant interaction between point arrangement and stimuli type, $F(2, 90) = 3.34$, $p = .040$, $\eta_p^2 = .069$. Follow-up analyses of simple main effects revealed that participants more accurately detected faces when presented with neutral stimuli ($M = 90.00\%$ correct, $SD = 16.85$) versus emotional stimuli ($M = 84.06\%$, $SD = 14.56$) in schematic condition, $F(1, 90) = 4.97$, $p = .028$. This simple main effect of stimuli type was not significant in either of the other two point arrangement conditions.

Finally, there was no significant interaction between presentation mode and stimuli type, $F(1, 90) = 2.02$, $p = .158$, $\eta_p^2 = .022$, and no significant three-way interaction, $F(2, 90) = 0.29$, $p = .750$, $\eta_p^2 = .006$.

To address the overarching research question of whether or not adults can accurately detect upright faces from limited point-light information, responses in each of the six between-subjects conditions were compared to 50% chance using separate single-sample *t*-tests. Response accuracies in each of the six conditions (collapsed across emotional and neutral stimuli) were significantly above chance, $t(15) = 3.06 – 19.06$, p's $\leq .008$.

Lastly, differences in responses depending on distractor type were analyzed using a paired sample *t*-test. This analysis revealed a significant difference in responses depending on the type of distractor presented, $t(95) = 5.88$, $p < .001$. Across conditions, responses were significantly more accurate on trials with inverted distractors ($M = 87.92\%$ correct, $SD = 22.19$) than on trials with scrambled distractors ($M = 72.60\%$, $SD = 18.37$).

2.2.4 Point Movement Analysis

A secondary analysis relates to the distance traveled by each point in each display, in order to determine if response accuracy relates to the total motion generated in each display. For each of the 30 displays (3 point arrangements x 10 unique expressions/movements), the pixel location of each tracked point in each frame of the display was exported from Adobe AfterEffects CS 5. Using the linear distance formula $d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$, the distance traveled by each point between each frame was calculated. These values were then summed to estimate the total distance traveled across all points in each video display (see Table 1).

Table 1

Total point movement (pixels) within each point-light display as a function of stimuli type (SCH Schematic, BH = Bottom-heavy, BA = Bilaterally asymmetric).

	Anger	Fear	Joy	Sad	Surprise	Blink	Blow	Chew	Talk	Yawn
SCH	514	882	641	414	826	693	690	2535	953	1632
BH	455	869	715	443	840	701	672	3570	1117	1756
BA	486	875	607	407	800	690	630	2844	901	1685

With all items included, the correlation between response accuracy and total motion was not significant, Pearson $r(480) = .06$, $p = .198$. However, it may be important to consider that the total point movement in the chewing displays is very high compared to the other displays. With chewing displays excluded from the analysis, the correlation between total point movement and response accuracy is significant, Pearson $r(432) = .15$, $p = .002$.

2.3 Discussion

The results from Study 1 reveal that face detection was more accurate in response to dynamic displays in the bottom-heavy point arrangement condition, but not the others. In addition, face detection was overall more accurate in response to the schematic point arrangements when compared to both the bottom-heavy and bilaterally asymmetric point arrangements. Comparisons of responses across stimuli types revealed only a significant difference in the schematic condition, where neutral stimuli were recognized more accurately. Finally, across all six between-subjects conditions, average response accuracies were significantly greater than 50% chance.

A primary question addressed by this study was whether or not adults could successfully detect upright faces from isolated motion information, when presented in contrast to inverted and scrambled motion displays. Average response accuracies were significantly above chance in every condition, which suggests that adults were able to recognize faces across all point arrangements, and regardless of whether or not motion information was available. These results substantiate claims of adults' face expertise (e.g., Carey, 1992) by demonstrating that face detection is possible even with very limited static point-light information, and even when it is arranged in a way that does not resemble a face.

In addition, a comparison of responses by distractor type revealed that responses were significantly more accurate when inverted distractors were presented. First, this suggests that participants understood the task, and were capable of correctly rejecting upside down facial PLDs even though they were still intact “faces”. Another consideration is that the starting point arrangement was preserved in the scrambled distractors, but not the inverted ones. Participants may have been able to correctly reject inverted PLDs based on clear differences in starting point arrangement alone. This finding extends studies demonstrating the facial inversion effect with face images by showing that adults interpret upright PLDs differently than inverted ones.

To determine whether motion information is beneficial in interpreting facial PLDs, I compared response accuracies across static and dynamic presentation modes. Although the hypothesized main effect of motion was not significant, an interaction between point arrangement and presentation mode revealed that face detection in response to bottom-heavy displays was significantly more accurate when motion information was available. This difference suggests that motion information is beneficial in certain configurations of facial PLDs, and that disrupting top-heavy asymmetry may have a greater effect on face processing from PLDs than disrupting bilateral symmetry.

Several studies have documented infants’ preferences for top-heavy asymmetric stimuli (see Simion, et al., 2003 for review), whereas the importance of bilateral symmetry has been less explored. Top-heavy asymmetry may be more important because it reflects a permanent characteristic of faces (i.e., position of the eyes and mouth). In contrast, bilateral symmetry can be altered in natural ways (e.g., contracting facial muscles on one side of the face). The current study fits with past infant research and suggests that top-heavy asymmetry directs even adults’ attention to faces. Still, accuracy was above 50% chance across all conditions, including in response to static bottom-heavy displays. Thus, motion is not *critical* for face detection from bottom-heavy displays, but it does aid face detection.

Study 1 also used three different point arrangements, to determine whether point configuration is an important cue in interpreting PLDs. Face detection was overall more accurate in response to schematic displays when compared to bottom-heavy and bilaterally asymmetric ones. As expected, adults' ability to interpret the PLDs as faces was better when the points were arranged in a face-like way. This finding also extends prior work demonstrating the importance of top-heaviness and bilateral asymmetry in infant face perception (e.g., Simion, et al., 2003) by showing that even adults are sensitive to these cues in the context of facial PLDs.

Past work considering point placement in facial PLDs has found that recognition of certain emotions is aided by the motion information conveyed in either the top or bottom portion of the face (Bassili, 1979). Point arrangement has not been otherwise explored in studies using facial PLDs. The current findings suggest that this factor should be considered more carefully. Still, in Study 1, the point arrangements were consistent across each of the emotional expressions and movements within each condition. Future studies could assess which points are most important for detecting a face from each type of movement. For example, the points around the mouth may be most important for detecting a face from chewing, whereas the points around the eyebrows may be more important for detecting a face from blinking.

The final aim of Study 1 was to evaluate the influence of emotional significance and point arrangement on face detection from isolated motion, which was presented in PLDs. Past work with face images across various cognitive tasks suggests that emotionally valenced stimuli capture attention and aid face detection. In contrast, the current results showed no main effect of emotional significance. Across presentation modes and point arrangements, there was no significant difference in accuracy by stimuli type. There was, however, an interaction between stimuli type and point arrangement, such that faces were more accurately identified from neutral movements in the schematic condition.

Although this benefit of neutral stimuli was unexpected based on past work, it is possible that the stimuli used in the neutral condition are more naturalistic (i.e., we often see others talking, chewing, or yawning, but exaggerated displays of emotion are rare in real life). Thus, when points are arranged in a "face-like" way, it may be the case that face detection is easier when more natural or realistic movements are used. There is considerable work examining face processing as it relates to characteristic motion patterns generated by speech (e.g., Guellai, et al., 2011; Spencer, et al., 2006), but other neutral non-rigid acts such as chewing and yawning have not been explored. Future work could examine differences amongst artificially- and naturally-elicited facial movements to probe the effect of "realistic" motion.

Taken together, the results from Study 1 broadly suggest that the arrangement of points, and in some cases, the availability of motion information and emotional significance of stimuli influence face detection from PLDs. Future work with PLDs should consider these visual cues, as they have not been fully considered in past work using the PLD technique with faces. The results from this study could be extended to a developmental investigation to determine if the visual cues explored here are also important in detecting faces from PLDs throughout childhood.

3 STUDY 2

3.1 Method

3.1.1 Development of Emotion Recognition from Isolated Motion

The aim of Study 2 is to investigate the role of isolated motion cues in identifying emotional expressions. Adults viewed both static and dynamic presentations of emotion PLDs, to evaluate the benefit of motion in recognizing emotions from these displays. In order to assess the how motion influences the development of emotion recognition, children were tested only with dynamic PLDs. Comparisons between children's and adults' responses to the dynamic displays assess the effect of age on emotion recognition from PLDs.

This study included children aged 3-8 years and adults, which represents a wider age range than has been used in previous developmental investigations of emotion recognition from facial motion. This allows me to determine at what age children show adult-like levels of performance in identifying emotions from isolated motion cues; studies of bodily motion suggest it may not occur until age 8 (Ross, et al., 2012). In addition, testing a wider age range allows for investigation of whether the development of emotion recognition depends on the motion being recognized; studies using face images suggest correct identification of certain expressions may not occur until age 9 (Durand, et al., 2007).

3.1.2 Participants

Adults (n = 44; range 18-69 years, M = 20.73, SD = 7.59; 6 males) were recruited from the Georgia State University research participants pool. Children (n = 167; range 3-8 years; M = 5.51, SD = 1.63; 86 males) were recruited at the Fernbank Museum of Natural History in Atlanta, GA. Twenty-four additional children were excluded from the dataset because they did not complete all test trials. Informed consent was obtained from parents, and assent was obtained from children aged 6 and older. Children were separated into three groups based on age, 3-4 year olds (*n* = 54; 33 males), 5-6 year olds (*n* = 59; 29 males), and 7-8 year olds (*n* = 54; 22 males). These groupings are consistent with past studies examining the development of emotion recognition in childhood (e.g., Doi, et al., 2008; Durand, et al., 2007). In the overall sample, 57.82% of participants identified as White, 10.90% as mixed race, 10.43% as Black/African American, 9.48% as Asian, 6.16% as Hispanic/Latino, and 5.21% did not specify. This sample is taken to represent the diversity of the metro Atlanta area.

3.1.3 Materials

The bilaterally asymmetric emotional PLDs from Study 1 were used. This same subset of the six basic emotions was used to accommodate time constraints for testing children, and because it is consistent with past studies examining the development of emotion recognition from static images (e.g., Herba, et al., 2006) and dynamic displays (Doi, et al., 2008). In addition, disgust, seems to be particularly difficult for children and adults to recognize, based on research using both static and dynamic presentations of facial expressions (see Widen & Russell, 2013, for review).

The bilaterally asymmetric point configuration was chosen in order to make the task appropriately difficult for adults and children. Past work shows that event infants are sensitive to the bilateral symmetry of faces (Rhodes, Geddes, Jeffery, Dziurawiec, & Clark, 2002), and pilot data suggested that adults and children responded near ceiling levels in response to video stimuli when the points were arranged symmetrically around the eyes and mouth. Asymmetric displays were used to obtain greater variability in response accuracies. In addition, these stimuli were preferred over the bottom-heavy displays because past research examining emotion recognition from PLDs suggests a differential influence of motion from the top and bottom halves of the face, depending on the emotion to be recognized (Bassili, 1979). Specifically, this study found that motion from the top half of the face is critical for detecting anger, whereas motion from the bottom half is critical for detecting joy and sadness, and motion from both halves are important for detecting surprise and fear. Thus, the bottom-heavy displays might have produced differences in emotion recognition that were an artefact of the stimuli rather than an effect of development. For the static condition, screenshots of the PLDs at their maximum expression were used.

As with Study 1, Study 2 was implemented using E-Prime 2.0 software on a laptop computer. Participants were asked to choose which of two concurrently presented PLDs matched an emotion label. These labels were “angry”, “afraid”, “happy”, “sad”, and “surprised”, and are consistent with those used in past studies examining emotion recognition in childhood (Bullock & Russell, 1985; Camras & Allison, 1985; Widen & Russell, 2003).

Full-light versions of the emotional expressions used to generate the PLDs in Study 2 were also validated through a pilot study. Adults’ (n = 13) recognition of the five emotions from the full-light displays was assessed using the same task format as was used in Study 2. This was done to ensure that adults could correctly recognize the five emotions when presented in full-light displays (i.e., a typical face video rather than a degraded PLD), and that they were appropriate stimuli for the PLD task. Overall response accuracies in this pilot task (M = 98.46% correct, SD = 12.33%, range = 94.23 – 100% for each emotion) suggest that the facial expressions used to generate the PLDs were sufficient and accurate representations of each of the five emotions tested.

3.1.4 Procedure

Adult participants were tested individually in a university lab room. Children were tested at a museum where they had free access to several activities at a large table, which was positioned near a child-friendly exhibit. When a child chose to participate in this experiment, they stood or sat across from the laptop computer running the task. An experimenter sat at the table next to the computer. Child participants indicated their responses by pointing to the screen, and an experimenter controlled the laptop accordingly (i.e., inputting corresponding key presses). Adult participants moved through the experiment by themselves by following the displayed prompts. The practice trials were identical to those used in Study 1, and children were given additional verbal prompts (e.g., “What does this look like?” on the screen showing a woman doing jumping jacks, and “Can you point to the video that shows jumping jacks?” on the screen showing two PLDs).

During test trials, participants were asked to choose which one of two PLDs matched a provided emotion label (see Figure 7). Participants were never explicitly told that they were viewing faces, and children received only general verbal prompts throughout the experimenter (e.g., “Which one looks happy?” or “Which video looks surprised?”).

Adults completed 20 trials, to assess performance on each possible combination of PLDs and emotion labels. In a between-subjects manipulation, adults viewed either static or dynamic PLDs. Comparisons between these two conditions assess the influence of motion information on response accuracy. Children were randomly assigned to one of two stimuli sets including a subset of 10 dynamic PLD trials; each set included two trials matching each emotion to its label. This is an appropriate task length for children’s sustained interest. The presentation order of stimuli was randomized and the location of the correct response (left/right side) was counterbalanced.

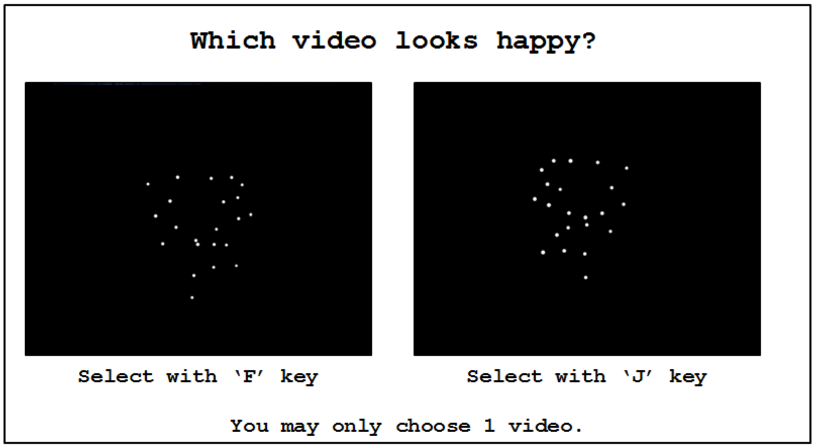

Figure 7. Example emotion recognition trial (joy versus fear).

3.1.5 Design

Adults were tested in a 2 (presentation mode; static or dynamic) x 5 (emotion; anger, joy, fear, sadness, and surprise) repeated-measures design. The developmental investigation utilized a 4 (age group; 3-4, 5-6, 7-8, and adult) x 5 (emotion) repeated-measures design.

3.2 Results

3.2.1 Scoring

Each participant's responses were recorded as correct/incorrect (1/0) in E-Prime. Response accuracies were then converted to percentages.

3.2.2 Preliminary Analyses

A preliminary analysis revealed no significant gender differences in overall accuracy, $t(209) = 1.69$, $p = .093$. Responses were collapsed across genders for the main analyses. Across groups, the assumption of homogeneity of variances was met using Mauchly's test of sphericity, $\chi^2(9) = 9.63$, $p = .381$, but response accuracies violated assumptions normality (Shapiro-Wilk *p*'s

≤ .001). Parametric tests are reported here, and nonparametric tests revealed similar patterns of findings (see Appendix).

3.2.3 Main Analyses

3.2.3.1 Adults: Static and Dynamic Displays

First, adults' responses across the dynamic and static presentation conditions were analyzed using a 2 (presentation mode) x 5 (emotion) repeated measures ANOVA. These results are shown in Figure 8. This analysis revealed a significant main effect of presentation mode, $F(1,42) = 8.52$, p = .006, $\eta_p^2 = .169$. Across the five emotions tested, adults were more accurate in identifying the correct emotion in the dynamic condition (*M* = 72.50% correct, *SD* = 12.51) than in the static condition (*M* = 61.75%, *SD* = 11.73).

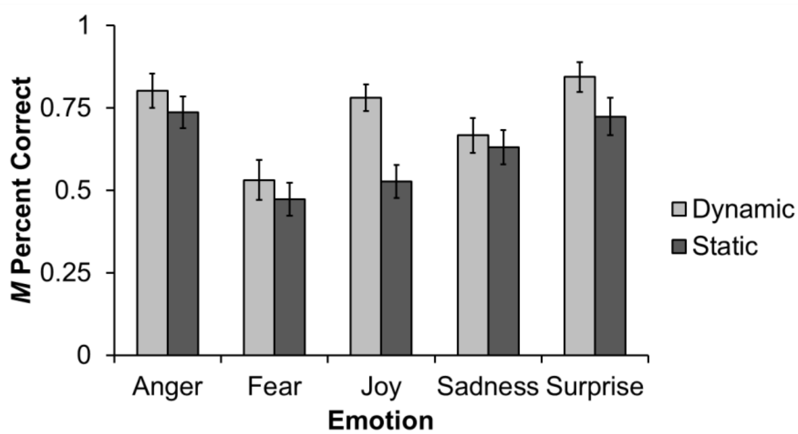

Figure 8. Adults' average response accuracies (+/- SE) across presentation conditions.

There was also a significant main effect of emotion, $F(4, 168) = 11.62$, $p < .001$, $\eta_p^2 =$ .217. Post-hoc pairwise comparisons revealed that, across presentation modes, adults were more accurate in recognizing surprise (*M* = 79.55%, *SD* = 23.67) than fear (*M* = 50.00%, *SD* = 26.41), joy (*M* = 66.48%, *SD* = 24.08), and sadness (*M* = 64.77%, *SD* = 24.30), Bonferroni-corrected *p*'s ≤ .044. In addition, anger (*M* = 77.27%, *SD* = 23.39) was recognized more accurately than fear and sadness, Bonferroni-corrected p's $\leq .048$. There were no significant differences amongst any of the other emotions. Lastly, there was no significant interaction between presentation mode and emotion, $F(4, 168) = 1.56$, $p = .186$, $\eta_p^2 = .036$.

Adults' responses to each of the five emotions across both presentation modes were then compared to 50% chance, using separate single-sample t-tests. These analyses revealed that, in the static condition, adults responded significantly above chance when identifying the angry, sad, and surprised emotion displays, $t(19) = 2.52 – 5.15$, p's $\leq .021$. In the dynamic condition, adults responded significantly above chance when identifying anger, joy, sadness, and surprise, $t(23) = 3.11 – 7.69$, p's $\leq .005$. Thus, across both presentation modes, adults did not recognize fear above chance levels, but did so for anger, fear, and sadness. Adults recognized joy above chance only in the dynamic condition.

3.2.3.2 Adults and Children: Dynamic Displays

Children's and adults' responses to the dynamic displays were analyzed using a 4 (age group) x 5 (emotion) repeated-measures ANOVA. These results are shown in Figure 9. This analysis revealed a significant main effect of age, $F(3, 187) = 12.70$, $p < .001$, $\eta_p^2 = .169$. Post-hoc pairwise comparisons revealed that adults ($M = 72.50\%$, $SD = 12.51$) were overall significantly more accurate in recognizing emotions from PLDs than all three child groups ($M_{3\text{-}4} = 49.44\%$, $SD = 14.85$; $M_{5\text{-}6} = 54.07\%$, $SD = 16.20$; $M_{7\text{-}8} = 59.26\%$, $SD = 17.68$), Bonferroni-corrected p's $\leq .005$.

Figure 9. Adults' and children's average response accuracies (+/- SE) separated by emotion type.

There was also a significant main effect of emotion, $F(4, 748) = 5.66$, $p < .001$, $\eta_p^2 = .029$. Post-hoc comparisons revealed that, across age groups, surprise (M = 63.74%, SD = 33.11) was more accurately recognized than both fear (M = 50.92%, SD = 34.44) and sadness (M = 53.40%, SD = 33.46), Bonferroni-corrected p's $\leq .013$. There were no significant differences in recognizing anger (M = 56.41%, SD = 33.56) or joy (M = 58.25%, SD = 34.04). The interaction between age group and emotion was not significant, $F(12, 748) = 1.67$, $p = .070$, $\eta_p^2 = .026$.

Separate one-way ANOVAs were used to further clarify when recognition of each emotion from PLDs reaches adult levels of accuracy. These analyses revealed significant group differences in recognition of anger, joy, sadness, and surprise, $F(3, 187) = 4.52 – 6.95$, p's $\leq .004$, but there were no group differences in recognition of fear. Post-hoc pairwise comparisons revealed that adults recognized anger, joy, and surprise more accurately than the 3-4 and 5-6 year old groups, Bonferroni-corrected p's $\leq .020$. In regards to sadness, both adults and 7-8 year olds recognized it more accurately than the 3-4 year olds, p's $\leq .025$.

Each age group's response accuracies for each of the five emotions were then compared to 50% chance using separate one-sample *t*-tests. Children 3- to 4-year-old group recognized surprise significantly above chance, $t(53) = 2.13$, $p = .038$. No other emotions were recognized at above chance levels by the 3- to 4-year-olds, and the 5- to 6-year-olds did not recognize any emotions at above chance. Seven- to 8-year-olds, in contrast, showed above-chance recognition of anger, joy, sadness, and surprise, $t(53) = 2.11 – 3.50$, p's $< .040$. However, the oldest children did not recognize fear at above chance. Adults in the dynamic condition identified all emotions except fear above chance (see above).

3.2.4 Point Movement Analysis

Total point movement in each bilaterally asymmetric emotion display was calculated using the methods described in Study 1. These values are available in the first five columns of Table 1 (above).

Total motion did not correlate with response accuracy in the emotion recognition task, Pearson $r(950) = .01$, $p = .733$. However, across all age groups, recognition of fear was consistently at chance levels. Thus, it may be justified to exclude this emotion from further analyses. With fear excluded, the correlation between response accuracy and total point movement in the emotion recognition task is significant, $r(760) = .10$, $p = .004$.

3.3 Discussion

Study 2 evaluated adults' and children's ability to make discriminating judgments from isolated facial motion cues generated by emotional expressions (using the bilaterally asymmetric emotional PLDs from Study 1). Specifically, participants were asked to select which one of two alternative displays matched a provided emotion label. Children viewed only dynamic PLDs, whereas adults completed this task with both dynamic and static stimuli.

Across the five emotions tested, adults' responses in the dynamic and static presentation conditions revealed a benefit of motion information in deciphering facial PLDs, and suggest an influence of motion on emotion recognition. This finding also suggests that motion information supports emotion recognition when features are not visible. Subsequent comparisons revealed that two emotions (anger and surprise) were easier to recognize than fear. Thus, recognition of certain emotions appears to be influenced by the presence of motion information, whereas others (in particular, fear) may require visible features.

Still, motion information was not necessary for adults to correctly interpret the PLDs at above chance levels for three of the five emotions tested (anger, sadness, and surprise). Motion only appeared critical for correctly interpreting joy. This indicates that, although emotion recognition is generally better when motion information is available, static PLDs are sometimes sufficient. Overall, these findings support prior work demonstrating that adults can recognize emotions from dynamic PLDs at above-chance levels (Bassili, 1979; Doi, et al., 2008).

In addition, this study extends past work by demonstrating that emotion recognition is possible with fairly limited information. Our PLDs contained considerably fewer points than have been used in past studies, and participants were never explicitly told that they were viewing faces. The stimuli were also bilaterally asymmetric, which may have hindered participants' ability to spontaneously interpret them as faces.

Comparisons between children's and adults' responses to the dynamic PLDs showed clear development of emotion recognition abilities, and across age groups, recognition was better for certain emotions (surprise) versus others (fear and sadness). Emotion recognition from dynamic PLDs showed significant improvement with age, which is consistent with past work using static face images (e.g., Durand et al., 2007; Widen & Russell, 2003). However, the development of emotion recognition from isolated facial motion cues appears to be delayed relative to recognition from facial features. For example, some studies using face images find near-ceiling recognition abilities for basic emotions by children as young as five (e.g., Bullock & Russell, 1985; Camras & Allison, 1985; Herba, et al., 2006). Still, the current results show that children can correctly decipher facial expressions of emotion using only motion cues, when featural information is not available. In addition, the timeline of emotion recognition from isolated motion found here aligns with prior work examining emotion recognition from full-body PLDs (Ross, et al., 2012).

Separate analyses for each emotion revealed that recognition for three emotions (anger, joy, and surprise) in the two youngest groups was significantly less accurate than adult levels; however, responses from the 7- and 8-year-old children did not differentiate from either of the younger child groups nor the adults. In addition, 7- and 8- year olds and adults recognized sadness significantly more accurately than the 5- and 6-year olds. Developmental patterns are further clarified by comparisons to 50% chance; children aged 7 to 8 and older responded at above chance levels for anger, joy, sadness, and surprise, whereas younger children were not consistently able to reliably identify any of the emotions tested (3- and 4-year-olds' above-chance recognition of surprise was the only example of reliable recognition in these younger groups).

However, it may be important to note that adults were tested in a laboratory setting, whereas children were tested in a museum where several other tasks and exhibits were visible and available. This environment may have been distracting and hindered children's performance on the emotion recognition task. Although the child data presented here may be ecologically valid (i.e., in real life, children process facial expressions of emotion amongst distraction), the differences between children and adults found here may be more pronounced due to the differences in testing conditions. Future studies could equate for testing conditions by either testing all participants in a laboratory or recruiting exclusively at a museum.

These results support proposals that the developmental trajectory of emotion recognition depends on the emotion to be recognized (e.g., Durand, et al., 2007). In particular, fear was not reliably recognized by any group. Some have suggested that understanding of fear and anger is delayed due to continuing maturation of the prefrontal cortex and amygdala in late childhood and adolescence (as these are primary neural areas for processing these emotions; see Thomas, et al., 2007). It is also possible that accurate recognition of fearful expressions relies critically on featural information. Some combination of these factors may explain participants' inability to identify fear in this task.

Although the current findings are encouraging, more work is needed to clarify the developmental patterns of recognition of emotions from facial PLDs. In particular, it is unclear whether participants in this study interpreted the displays as faces and then mapped them onto their existing representations of facial expressions of emotion, or if the emotions were processed in another (perhaps implicit) way. Past work shows that even preschool-age children can freely and correctly produce emotion words to categorize pictures of faces (e.g., Widen & Russell, 2013), but it is unclear whether children can use provided emotion words to shape interpretations of unfamiliar stimuli. A future study may consider asking participants to describe the displays at the end of the task (e.g., "Can you explain what you saw?"); however, verbal responses from young children might be unreliable.

The current study shows that developmental patterns in emotion recognition in response to isolated motion cues mirror those found using static face images. Thus, even children are sensitive to natural facial motion and can use it to make discriminating judgments (e.g., identify emotional expressions) about unfamiliar face stimuli, with relatively little environmental support. Past work has also pointed to the importance of features in recognizing emotions; this study shows that visible features are not necessary for emotion recognition when motion information is available. These findings support the possibility that motion is an important cue in face processing across development.

Lastly, future studies could tease apart potential explanations for age-related improvements in this task. It has been suggested that the development of emotion understanding is explained by refining boundaries amongst mental representations of emotion; for example, young children's errors on free-labeling tasks show that negative emotions are often confused with one another (Bullock & Russell, 1985). In addition, an increasing vocabulary for descriptions of emotional experiences may drive emotion development; studies find positive relationships between verbal ability and emotion recognition (De Stasio, Fiorilli, & Di Chiacchio, 2014). A growing repertoire of direct experiences with different emotions, including observations of others' facial expressions of emotion, may also play a role. For example, one study found that children who had experienced physical abuse showed better recognition of anger than typical children (Pollak, Messner, Kistler, & Cohn, 2009). Maturation of specific brain areas, including the amygdala and prefrontal cortex, may also explain changes in emotion recognition in adolescence (Thomas, DeBellis, Graham, & LaBar, 2007). Lastly, interpersonal factors are also shown to play a role in the development of emotion understanding; in one study, parents' ability to mentalize their children's emotional responses predicted improvements in children's emotion understanding between ages four and six (Karstad, Wichstrom, Reinfjell, Belsky, & Berg-Nielsen, 2015). In consideration of the current task, older children may have shown improved performance because they were better able to handle task demands (i.e., they were able to pay attention to a computerized task in a loud and busy museum environment).

Each of these alternative hypotheses could be evaluated in future tasks using emotional PLDs. For example, a free-labeling task in which children produce the emotion label for each PLD could assess whether young children are more likely to confuse negative emotions (e.g., label a sad PLD as angry or afraid), which would align with the theory of young children's fuzzy boundaries between mental representations of emotion. According to the fuzzy boundaries theory, distinguishing anger from sadness should be more difficult than distinguishing anger from surprise. However, data from the current study suggest that this is not the case with emotional PLDs. For example, when children were required to match an angry PLD to its word label, the youngest group responded correctly 48% of the time when the distractor was a sad PLD versus 44% of the time when the distractor was a surprised PLD. Similarly, the oldest child group correctly matched anger 50% of the time when the distractor was sad and 46% of the time when the distractor was surprised. Still, given that each child only saw a subset of PLD and word label combinations, the current data have limited ability to evaluate this theory.

In consideration of other developmental theories, the addition of a standardized language measure (e.g., the Peabody Picture Vocabulary Test), or working memory task (e.g., the N-back) could assess the relationship between vocabulary or executive function and emotion recognition from PLDs. Targeted recruitment of special populations could address the role of experience in emotion recognition; for example, a future PLD study could include a comparison group of children of depressed mothers (who may receive less daily exposure others' expressions of emotion). Larger studies including emotional measures from parents and peers could assess the relationship between the development of emotion recognition from PLDs and interpersonal factors. Although the mechanisms of emotion development were not directly tested in the current study, there are several ways that future work could address this question using PLD stimuli.

4 GENERAL DISCUSSION

Taken together, the results from these two studies evaluate the role of motion information in face detection and the development of emotion recognition, and clarify under which conditions motion information is beneficial for correctly interpreting facial PLDs. Although there was no overall benefit of motion information in the face detection task used in Study 1, motion was helpful in Study 2 when participants were asked to make more discriminating judgments regarding the facial PLDs (i.e., which emotion was being expressed). Past work with full-body PLDs finds that adults can accurately discriminate additional information from isolated motion cues, such as the gender of an actor (Mather & Murdoch, 1994). Future work with facial PLDs could explore what other types of information, in addition to expressions of emotion, can be gleaned from these displays.

In addition, these studies suggest that point arrangement is an important factor to consider in experiments using facial PLDs. In Study 1, there were overall variations in performance based on the arrangement of PLD points, and results also showed that that the benefit of motion information in the face detection task depended on the how the points are arranged. In Study 2, all participants viewed bilaterally asymmetric displays, but pilot data suggested that performance was near ceiling for some of the emotions in face-like point arrangements. These results demonstrate the point arrangement should be a critical consideration for work using facial PLDs. Future studies could further delineate which points are most important for detecting faces or recognizing certain expressions, or test fewer numbers of points to identify which are most critical in face processing from PLDs.

Another general finding from these studies concerns the relationship between total point movement and response accuracy. In both Study 1 and Study 2, the correlation between point movement and accuracy was not significant when all items were considered. However, certain items may have been problematic for these analyses. For one, the chewing displays involved a disproportionately high level of total point movement; second, recognition of fear was considerably lower than for the other emotional displays. With these items excluded, the correlations were significant, but small (*r* = .10 – .15). This suggests that the results of Studies 1 and 2 may not be primarily explained by perceptual sensitivity to total motion patterns. Still, future studies may consider controlling for total point movement. Future work could also explore the role of point movement by comparing emotion recognition from PLDs generated from both exaggerated emotional expressions and fleeting micro-expressions. It is possible that emotional expressions with more total movement are easier to recognize because, at their full expression, they represent a greater deviation from a neutral face.

4.1 Limitations and Future Considerations

One limitation to the current work is that only response accuracies were included in the final analyses. More sensitive response measures, such as reaction times (RTs), may help us better understand how children and adults process the PLDs. These measures were not included in the current project because each PLD video differs in length, which confounds estimates of RTs, and children did not enter responses directly.

In particular, a comparison of RTs in response to the emotional and neutral stimuli used in Study 1 may better assess whether emotional PLDs capture attention. In regards to Study 2, collecting direct responses from children, rather than having them point to the screen, could help assess whether or not they were paying attention to the displays. Pointing has been used as a response measure for children as young as age two (e.g., Dittmar, Abbot-Smith, Lieven, & Tomasello, 2011), and was developmentally appropriate for all children tested. However, qualitative observations revealed that younger children often responded before watching the PLDs completely, which suggests that they were not fully attending to or engaged in the task. Collecting direct RT measures could assess this possibility and shed light on how developmental differences in sustained attention may affect performance on this task. Future work could implement touch screen technology with highly controlled stimulus presentations to allow for collection of reliable RTs from both adults and children.

Future investigations could also examine the basic emotions that were not tested here due to time constraints (i.e., disgust). Disgust is particularly difficult for children to recognize (Widen & Russell, 2013) and seems to be problematic for adults as well (Widen & Russell, 2008). Perhaps showing a dynamic PLD of a 'disgusted' expression could help children and adults better identify it in real-life interactions. The current work represents an initial foray into examining emotion recognition from isolated motion cues, but there remain several future avenues for examining emotion understanding with facial PLDs.

4.2 Facial PLDs with Other Populations

The facial PLD stimuli created for this dissertation could be used to asses face processing from isolated motion cues in additional populations. Two primary candidates for investigation are individuals with autism spectrum disorder (ASD) and infants. In regards to ASD, research has found that face processing is disrupted in individuals with this disorder, and this may be partially due to an aversion to eye contact (Golarai, Grill-Spektor, & Reiss, 2006). Other research finds reduced visual attention to facial features in ASD (Pelphrey, et al., 2002).

Each of these studies has investigated how people with ASD process and respond to facial features. It is possible that children with ASD are better able to recognize faces and emotions from PLDs, where features are absent and therefore less aversive. This research could lead to using PLDs for targeted interventions, in which children with ASD are taught to respond to facial PLDs before being introduced to full faces in live interactions. A recent clinical trial also found that children with ASD could improve their face recognition abilities via engagement in a computerized task (Tanaka, et al., 2010). Part of the task involved reinforcement of visual attention to faces, and the children were somewhat older (M = 10.5 years). Younger children with ASD may respond better to attention-reinforcement to facial PLDs. Early screening measures could also make use of this proposed research, for example, by presenting young at-risk children with full faces and facial PLDs, and measuring whether they find one aversive but not the other. An aversion to a full face, but not a facial PLD, might provide an early signal of the abnormal face processing that is found in ASD.

In addition, the PLDs developed for this project could be used in future studies with typically developing infants. Using preferential looking paradigms, research with young infants could determine what types of facial motion processing capabilities are present from early in development. This would add to the greater body of literature examining infant face processing based on visual attention to static displays (e.g., Johnson, et al., 1991) and animated faces (e.g., Frank, et al., 2009). Recent work has probed the role of motion cues in infants' face perception (e.g., Guellaï, Coulon, & Streri, 2011; Spencer, O'Brien, Johnston, & Hill, 2006), but it remains to be seen if infants show the same preference for faces when motion is isolated and featural information is not present. For example, testing infants' orienting behavior to the upright versus inverted or scrambled dynamic PLDs used in Study 1 may reveal that infants prefer upright facial motion, as is found with static upright images and caricatures (e.g., Johnson, et al., 1991) and other types of biological motion (Simion, et al., 2008). In addition, the PLDs from Study 2 could be used to determine whether infants show an ability to discriminate basic emotional expressions from motion cues alone; such findings would align with past work using face images (e.g., Farroni, et al., 2005; Schwartz, et al., 1985). This and the aforementioned examples illustrate that there are many avenues of research left to be explored using facial PLDs.

4.3 Conclusions

Across two studies, this dissertation explores the importance of motion information, point arrangement, and emotional significance in the processing of facial PLDs. Results from Study 1 suggest that point arrangement is important in interpreting PLDs as faces, and even modulates the effects of motion information and emotional valence. Although point arrangement has not been systematically varied in past studies using facial PLDs, the current work shows that it should be considered carefully in future work with these stimuli. Results from Study 2 revealed a benefit of motion in discriminating emotions from PLDs, and that developmental patterns of emotion recognition from dynamic PLDs followed similar trajectories to those found with face images. These findings suggest an influence of facial motion on emotion recognition. Future studies with additional populations (including children with ASD and infants) could further assess how motion contributes to face processing and emotion recognition abilities.

REFERENCES

Adamson, L. B. and Frick, J. E. (2003). The Still Face: A history of a shared experimental paradigm. *Infancy, 4*(4), 451-473.

Alaerts, K., Nackaerts, E., Meyns, P., Swinnen, S. P., and Wenderoth, N. (2011). Action and emotion recognition from point light displays: An investigation of gender differences. *PLoS ONE, 6*(6), e20989.

Atkinson, A. P., Dittrich, W. H., Gemmell, A. J., and Young, A. W. (2004). Emotion perception from dynamic and static body expressions in point-light and full-light displays. *Perception, 33,* 717-746.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., and Plumb, I. (2001). The “Reading the Mind in the Eyes” test revised version: A study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, 42*(2), 241-251.

Bartlett, M. S., Littlewort, G., Frank, M., Lainscsek, C., Fasel, I., and Movellan, J. (2005). Recognizing facial expression: machine learning and application to spontaneous behavior. *Proceedings of the IEEE International Conference on Computer Vision and Pattern Recognition,* 568-573.

Bassili, J. N. (1978). Facial motion in the perception of faces and of emotional expression. *Journal of Experimental Psychology: Human Perception and Performance, 4*(3), 373-379.

Bassili, J. N. (1979). Emotion recognition: The role of facial movement and the relative importance of upper and lower areas of the face. *Journal of Personality and Social Psychology, 37*(11), 2049-2058.

Batty, M. and Taylor, M. J. (2003). Early processing of the six basic facial emotional expressions. *Cognitive Brain Research, 17*(3), 613-620.

Bullock, M. and Russell, J. A. (1985). Further evidence on preschoolers' interpretation of facial expressions. *International Journal of Behavioral Development, 8*, 15-38.

Bruce, V., Campbell, R. N., Doherty-Sneddon, G., Import, A., Langton, S., McAuley, S., and Wright, R. (2000). Testing face processing abilities in children. *British Journal of Development Psychology, 18*, 319-333.

Camras, L. A. and Allison, K. (1985). Children's understanding of emotional facial expressions and verbal labels. *Journal of Nonverbal Behavior, 9*(2), 84-94.

Carey, S. (1992). Becoming a face expert. *Philosophical Transactions of the Royal Society of London, Series B, 335*(1273), 95-103.

Chioro, P., and Valentine, T. (1995). An investigation of the contact hypothesis of the own-race bias in face recognition. *The Quarterly Journal of Experimental Psychology, 48*(4), 879-894.

de Heering, A., de Leidekerke, C., Deboni, M., and Rossion, B. (2010). The role of experience during childhood in shaping the other-race effect. *Developmental Science*, *13*(1), 181-187.

De Stasio, S., Fiorilli, C., and Di Chiacchio, C. (2014). Effects of verbal ability and fluid intelligence on children's emotion understanding. *International Journal of Psychology, 49*(5), 409-414.

Diamond, R. and Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology, General, 115*(2), 107-117.

Dittmar, M., Abbot-Smith, K., Lieven, E., and Tomasello, M. (2011). Children aged 2 ; 1 use transitive syntax to make a semantic-role interpretation in a pointing task. *Journal of Child Language, 38,* 1109-1123.

Dittrich, W. H. (1993). Action categories and the perception of biological motion. *Perception, 22*(1), 15-22.

Doi, H., Kato, A., Hashimoto, A., and Masataka, N. (2008). Role of biological-motion information in recognition of facial expressions by young children. *Perception, 37,* 1399-1411.

Durand, K., Gallay, M., Seigneuric, A., Robichon, F., and Baudouin, J. Y. (2007). The development of facial emotion recognition: The role of configural information. *Journal of Experimental Child Psychology*, *97*(1), 14-27.

Eastwood, J. D., Smilek, D., and Merikle, P. M. (2001). Differential attentional guidance by unattended faces expressing positive and negative emotion. *Perception & Psychophysics, 63*(6), 1004-1013.

Ekman, P., and Friesen, W. V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology*, *17*(2), 124-129.

Ekman, P. and Friesen, W. V. (1976). Measuring facial movement. *Environmental Psychology and Nonverbal Behavior, 1*(1), 56-75.

Ekman, P., Sorensen, E. R., and Friesen, W. V. (1969). Pan-cultural elements in facial displays of emotion. *Science*, *164*(3785), 86-88.

Emery, N. J. (2000). The eyes have it: The neuroethology, function and evolution of social gaze. *Neuroscience & Biobehavioral Reviews, 24*(6), 581-604.

Essa, I. and Pentland, A. (1997). Coding analysis, interpretation, and recognition of facial expressions. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 19*, 757-763.

Farroni, T., Johnson, M. H., Menon, E., Zulian, L., Farguna, D., and Csibra, G. (2005). Newborns' preference for face-relevant stimuli: Effects of contrast polarity. *PNAS, 102*(47), 17245-17250.

Fox, E., Lester, V., Russo, R., Bowles, R. J., Pichler, A., and Dutton, K. (2000). Facial expressions of emotion: Are angry faces detected more efficiently? *Cognition and Emotion, 14*(1), 61-92.

Frank, M. C., Vul, E., and Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition, 110*(2), 160-170.

Golarai, G., Grill-Spektor, K., and Reiss, A. L. (2006). Autism and the development of face processing. *Clinical Neuroscience Research, 6*, 145-160.

Goren, C. C., Sarty, M. and Wu, P. Y. (1975). Visual following and pattern discrimination of face-like stimuli by newborn infants. *Pediatrics, 56*(4), 544-549.

Grossman, E. D. and Blake, R. (2002). Brain areas active during visual perception of biological motion. *Neuron, 35*(6), 1167-1175.

Guellai, B., Coulon, M., and Streri, A. (2011). The role of motion and speech in face recognition at birth. *Visual Cognition, 19*(9), 1212-1233.

Herba, C. M., Landau, S., Russell, T., Ecker, C., and Phillips, M. L. (2006). The development of emotion-processing in children: Effects of age, emotion, and intensity. *Journal of Child Psychology and Psychiatry, 47*(11), 1098-1106.

Ichikawa, H., Kanazawa, S., Yamaguchi, M. K., and Kakigi, R. (2010). Infant brain activity while viewing facial movement of point-light displays as measured by near-infrared spectroscopy. *Neuroscience Letters, 482,* 90-94.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics, 14*(2), 201-211.

Johnson, M. H., Dziurawiec, S., Ellis, H., and Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition, 40*(1-2), 1-19.

Karstad, S. B., Wichstrom, L., Reinfjell, T., Belsky, J., and Berg-Nielsen, T. S. (2015). What enhances the development of emotion understanding in young children? A longitudinal study of interpersonal predictors. *British Journal of Developmental Psychology, 33,* 340-354.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., and Pascalis, O. (2007). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science*, *18*(2), 1084-1089.

Kestenbaum, R. and Nelson, C. A. (1990). The recognition and categorization of upright and inverted emotional expressions by 7-month-old infants. *Infant Behavior and Development*, *13*(4), 497-511.

Knight, B. & Johnston, A. (1997). The role of movement in face recognition. *Visual Cognition, 4(*3), 265-273.

Kozlowski, L. T. and Cutting, J. E. (1977). Recognizing the sex of a walker from a dynamic point-light display. Perception & Psychophysics, 21, 575-580.

Lander, K. & Bruce, V. (2000). Recognizing famous faces: Exploring the benefits of facial motion. *Ecological Psychology*, *12*(4), 259-272.

Langlois, J. H., Roggman, L. A., Casey, R. J., Ritter, J. M., Rieser-Danner, L. A., and Jenkins, V. Y. (1987). Infant preferences for attractive faces: Rudiments of a stereotype? *Developmental Psychology, 23*(3), 363-369.

Liu, J., Li, J., Feng, L., Li, L., Tian, J., and Lee, K. (2014). Seeing Jesus in toast: Neural and behavioral correlates of face pareidolia. *Cortex, 53,* 60-77.

Mather, G. and Murdoch. L. (1994). Gender discrimination in biological motion displays based on dynamic cues. *Proceedings: Biological Sciences, 258*(1353), 273-279.

Meissner, C. A. and Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law, 7*(1), 3-35.

Meissner, C. A., Brigham, J. C., and Butz, D. A. (2005). Memory for own- and other-race faces: A dual process approach. *Applied Cognitive Psychology, 19,* 545-567.

Morton, J. and Johnson, M. H. (1991). CONSPEC and CONLERN: A two-process theory of infant face recognition. *Psychological Reviews, 98*(2), 164-181.

O'Brien, J., Spencer, J., Girges, C., Johnston, A., and Hill, H. (2014). Impaired perception of facial motion in autism spectrum disorder. *PLoS ONE, 9*(7), e102173.

O'Toole, A. J., Roark, D. A., and Abdi, H. (2002). Recognizing moving faces: A psychological and neural synthesis. *TRENDS in Cognitive Sciences, 6*(6), 261-266.

Otsuka, Y., Konishi, Y., Kanazawa, S., Yamaguchi, M. K., Abdi, H., and O'Toole, A. J. (2009). Recognition of moving and static faces by young infants. *Child Development, 80*(4), 1259-1271.

Pascalis, O., de Haan, M., and Nelson, C. A. (2002). Is face processing species-specific during the first year of life? *Science, 296*(5571), 1321-1323.

Pascalis, O., de Viviés, X. D. M., Anzures, G., Quinn, P. C., Slater, A. M., Tanaka, J. W., and Lee, K. (2011). Development of face processing. *Wiley Interdisciplinary Reviews in Cognitive Science, 2*(6), 666-675.

Pelphrey, K. A., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., and Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders, 32*(4), 249-261.

Pezdek, K., Blandon-Gitlin, I., and Moore, C. (2003). Children's face recognition memory: More evidence for the cross-race effect. *Journal of Applied Psychology, 88*(4), 760-763.

Pollak, S. D., Messner, M., Kistler, D. J., and Cohn, J. F. (2009). Development of perceptual expertise in emotion recognition. *Cognition, 110(2),* 242-247.

Quinn, P. C., Yahr, J., Kuhn, A., Slater, A. M., and Pascalis, O. (2002). Representation of the gender of human faces by infants: A preference for female. *Perception, 31*(9), 1109-1121.

Rhodes, G., Geddes, K., Jeffery, L., Dziurawiec, S., and Clark, A. (2002). Are average and symmetric faces attractive to infants? Discrimination and looking preferences. *Perception, 31*(3), 315-321.

Rosenblum, L. D., Johnson, J. A., & Saldaña, H. M. (1996). Point-light facial displays enhance comprehension of speech in noise. *Journal of Speech and Hearing Research, 39*(6), 1159-1170.

Ross, P. D., Polson, L., and Grosbas, M. (2012). Developmental changes in emotion recognition from full-light and point-light displays of body movement. *PLoS ONE, 7*(9), e44815.

Rossion, B. and Curran, T. (2010). Visual expertise with pictures of cars correlates with RT magnitude of the car inversion effect. *Perception, 39*(2), 173-183.

Schwartz, G. M., Izard, C. E., and Ansul, S. E. (1985). The 5-month-old's ability to discriminate facial expressions of emotion. *Infant Behavior and Development, 8,* 65-77.

Simion, F., Macchi Cassia, V., Turati, C. and Valenza, E. (2003). Non-specific perceptual biases at the origins of face processing. In Pascalis, O. and Slater, A. (Eds.) *The Development of Face Processing in Infancy and Early Childhood* (pp. 13-25). Hauppauge, NY: Nova Science Publishers, Inc.

Simion, F., Regolin, L., and Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences of the United States of America, 105*(2), 809-813.

Simion, F., Valenza, E., Macchi Cassia, V., Turati, C., and Umilta, C. (2002). Newborns' preference for up-down asymmetrical configurations. *Developmental Science, 5*(4), 427-434.

Soken, N. H. and Pick, A. D. (1992). Intermodal perception of happy and angry expressive behaviors by seven-month-old infants. *Child Development, 63,* 787-795.

Sorce, J. F., Emde, R. N., Campos, J., and Klinnert, M. D. (1985). Maternal emotion signaling: Its effect on the visual cliff behavior of 1-year-olds. *Developmental Psychology, 21*(1), 195-200.

Spencer, J., O'Brien, J., Johnston, A., and Hill, H. (2006). Infants' discrimination of faces by using biological motion cues. *Perception, 35,* 79-89.

Sullivan, S., Ruffman, T., and Hutton, S. B. (2007). Age differences in emotion recognition skills and the visual scanning of emotion faces. *The Journals of Gerontology, Series B, Psychological Sciences and Social Sciences, 62*(1), P53-P60.

Tanaka, J. W. and Gordon, I. (2011). Features, configuration, and holistic face processing. In Calder, A. J., Rhodes, G., Johnson, M. H., and Haxby, J. V. (Eds.) *The Oxford Handbook of Face Perception* (pp. 691-706). Oxford University Press: New York, NY.

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., Brown, C., Stahl, S., Kaiser, M. D., and Schultz, R. T. (2010). Using computerized games to teach face recognition skills to children with autism spectrum disorder: The Let's Face It! program. *Journal of Child Psychology and Psychiatry, 51*(8), 944-952.

Thomas, L. A., DeBellis, M. D., Graham, R. and LaBar, K.S. (2007). Development of emotional facial recognition in late childhood and adolescence. *Developmental Science, 10*(5), 547-558.

Troje, N. F. and Westhoff, C. (2006). The inversion effect on biological motion: Evidence for a "life detector"? *Current Biology, 16*(8), 821-824.

Ullman, S. (1979). The interpretation of structure from motion. *Proceedings of the Royal Society of London, Series B, 203*(1153), 405-426.

Vuilleumier, P. (2005). How brains beware: Neural mechanisms of emotional attention. *TRENDS in Cognitive Sciences*, *9*(12), 585-594.

Walker-Andrews, A. S. (1997). Infants' perception of expressive behaviors: Differentiation of multimodal information. *Psychological Bulletin, 121*(3), 437-456.

Widen, S. C. and Russell, J. A. (2003). A closer look at preschoolers' freely produced labels for facial expressions. *Developmental Psychology*, *39*(1), 114-128.

Widen, S. C. and Russell, J. A. (2008). Children's and adults' understanding of the "disgust face". *Cognition and Emotion, 22*(8), 1513-1541.

Widen, S. C. and Russell, J. A. (2013). Children's recognition of disgust in others. *Psychological Bulletin*, *139*(2), 271-299.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81*(1), 141-145.

APPENDIX

Appendix A.1 Study 1: Nonparametric Results

A Mann-Whitney U test revealed no significant differences in response accuracies between the dynamic (*M* = 82.71% correct, *SD* = 14.22) and static presentation modes (*M* = 77.81%, *SD* 17.19; *U* = 981.00, *p* = .206). A Wilcoxon signed-rank test revealed no significant differences in responses to emotional stimuli (*M* = 79.58%, *SD* = 16.98) versus neutral stimuli (*M* = 80.94%, *SD* = 18.30; *Z* = -0.92, *p* = .360). A Kruskal-Wallis test revealed a significant effect of point arrangement, $\chi^2(2) = 13.18$, *p* = .001. Follow-up Mann-Whitney U tests revealed that responses in the schematic condition were significantly more accurate compared to the bottom heavy (*p* = .001) and bilaterally asymmetric (*p* = .003) conditions. Significance thresholds for all follow-up tests (including those reported below) were adjusted using the Holm method.

To assess the interaction between presentation mode and point arrangement, three separate Mann-Whitney U tests were conducted (response accuracies in each presentation mode were compared in pairwise fashion across each of the three point arrangement conditions). There were no differences by presentation mode in either the schematic (*U* = 94.50, *p* = .192) or bilaterally asymmetric (*U* = 126.00, *p* = .939) conditions. However, in the bottom-heavy condition, responses were significantly more accurate with dynamic presentations (*M* = 85.94%, *SD* = 8.98), versus static presentations (*M* = 64.69%, *SD* = 19.19; *U* = 45.00, *p* = .002).

To assess the interaction between point arrangement and stimuli type, three separate Wilcoxon signed-rank tests were used (responses to each stimuli type were compared in pairwise fashion across each of the three point arrangements). There were no significant differences by stimuli type in either the bottom-heavy (*Z* = -1.36, *p* = .173) or bilaterally asymmetric (Z = -0.07,

p = .501) conditions. However, in the schematic condition, performance was significantly more accurate in response to neutral stimuli (M = 90.00%, SD = 16.85), versus emotional stimuli (M = 84.06%, SD = 14.56; Z = -2.67, p = .008.

Appendix A.2 Study 2: Nonparametric Results

Appendix A.2.1 Adults: Static and Dynamic Displays

Overall response accuracies in static and dynamic presentation modes were compared using a Mann-Whitney U test. Responses were significantly more accurate in the dynamic condition (M = 72.50% correct, SD = 12.51), versus the static condition (M = 61.75%, SD = 11.73; U = 131.0, p = .009).

A Friedman test also revealed overall differences across each of the five emotions tested, $\chi^2(4) = 39.74$, $p < .001$. Follow-up Wilcoxon signed-rank tests revealed that anger (M = 77.27%, SD = 23.39), joy (M = 66.48%, SD = 24.08), sadness (M = 64.77%, SD = 24.30), and surprise (M = 79.55%, SD = 23.67) were recognized more accurately than fear (M = 50.00%, SD = 26.41; p's $\leq .008$). In addition, fear and surprise were recognized more accurately than sadness (p's $\leq .009$), and surprise was recognized more accurately than joy (p = .009).

Appendix A.2.2 Adults and Children: Dynamic Displays

A Kruskal-Wallis test revealed a significant effect of age on overall accuracy, $\chi^2(3) = 32.50$, $p < .001$. Follow-up Mann-Whitney U tests revealed that adults were overall more accurate than 3-4 year olds (M = 49.44%, SD = 14.85; $p < .001$), 5-6 year olds (M = 54.07%, SD = 16.20; $p < .001$), and 7-8 year olds (M = 59.26%, SD = 17.68; p = .002). In addition, 7-8 year olds were more accurate than 3-4 year olds (p = .004).

A Friedman test also revealed significant overall differences in the recognition of each emotion tested, $\chi^2(4) = 15.94$, $p = .003$. Follow-up Wilcoxon signed-rank tests revealed that surprise (*M* = 63.74%, *SD* = 33.11) was recognized more accurately than fear (*M* = 50.92%, *SD* = 34.44; $p < .001$) and sadness (*M* = 53.40%, *SD* = 33.46; $p = .002$).

Separate Kruskal-Wallis tests were used to analyze recognition of each emotion across age groups. These tests revealed differences across age groups in recognition of anger, joy, sadness, and surprise, $\chi^2(3) = 14.56 – 20.46$, *p*'s $\leq .002$. There were no group differences in recognition of fear, $\chi^2(3) = 2.77$, $p = .428$. Follow-up Mann-Whitney U tests revealed that adults recognized anger, joy, sadness, and surprise more accurately than the two youngest age groups (*p*'s $\leq .001 – .013$). In addition, the 7-8 year olds recognized sadness more accurately than the 3-4 year olds ($p = .005$).