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Brief report

Using "Bubbles" with babies: A new technique for investigating the informational basis of infant perception

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Abstract

The 'Bubbles' technique (Gosselin, F. & Schyns, P.G. (2001). Bubbles: A technique to reveal the use of information in recognition tasks. *Vision Research*, *41*, 2261–2271) has been widely used to reveal the information adults use to make perceptual categorizations. We present, for the first time, an adapted form of Bubbles, suitable for use with young infants.

Keywords: Bubbles; Methodology; Perception; Infancy; Face processing

Bubbles (Gosselin & Schyns, 2001) is a recently devised technique that allows a precise investigation of exactly what information is being used by an observer for a particular categorisation task. Bubbles operates by randomly sampling information in a stimulus space (e.g., facial information is revealed by a number of randomly allocated Gaussian windows) while observers attempt to classify the sampled information (e.g., according to its gender, identity or expression, depending on task). After sufficiently many trials (see Section 1), the stimulus space is exhaustively and uniformly sampled. From this unbiased sampling strategy, one can estimate the information biases of observers by computing how each information sample can independently determine categorization performance. Samples giving rise to significantly higher performance are called the 'diagnostic' regions of the input (e.g., the eyes of a face in gender recognition) for the categorization task at hand.[1]

To date, the Bubbles technique has never been used with developmental populations, but it potentially provides a useful platform with which to compare infants' and adults' use of information, as well as how the use of information by infants changes as they develop. In the following experiment we employed an adapted Bubbles technique to face processing in 7-month-old infants. Our objective, in this preliminary study, was to demonstrate the extension of the Bubbles technique to infant populations.

In our adapted version of Bubbles, infants are shown a small number of trials (up to 20), and looking time to the stimulus is measured. Since this reduced number of trials does not permit sufficient sampling of the stimulus space,

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[1] Note that the Bubbles technique is not without its critics, see, e.g. (Murray and Gold (2004 – but see also Gosselin and Schyns' (2004) reply).

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trials are pooled across a number of infants for the analysis. Specifically, we aimed to collect at least 200 trials for our bubbles analysis.

In the present study, 7-month-old infants were shown their mother's face simultaneously with that of a stranger, with both faces in a presentation masked to reveal the same random information. Seven month olds were chosen to allow comparison with previous findings because much of the developmental literature on face perception has used this age group (e.g., Cashon & Cohen, 2001). Information was randomly sampled in the image space on each trial. The degree to which infants looked preferentially at the mother's side of the display and the degree to which they looked preferentially to the stranger were used in a regression analysis to compute the information used by infants when preferentially looking to each type of face.

1. Method

Participants were 16 healthy full-term 7-month-old infants. Data from three infants were excluded for fussing ($N=1$) and technical problems ($N=2$). The remaining 13 participants consisted of 4 male and 9 female infants, mean age 224 days (standard deviation 7 days).

Stimuli were individually created for each participant. High quality colour digital photographs (768 × 768 pixels) were taken of the infant's mother smiling. Mothers wore a shower cap to occlude their hairline and removed all jewellery. The pictures were paired with a picture of another mother with similar skin tone and hair colour (as judged by the experimenter), and the Bubbles procedure was applied. For each pair of faces, 20 pairs of photographs were prepared, with the same random locations of information samples ('bubble masks') on each face in the pair (40 Gaussian samples with a sigma equal to about 0.63° per image, with a different random bubble mask for each pair and observer (see

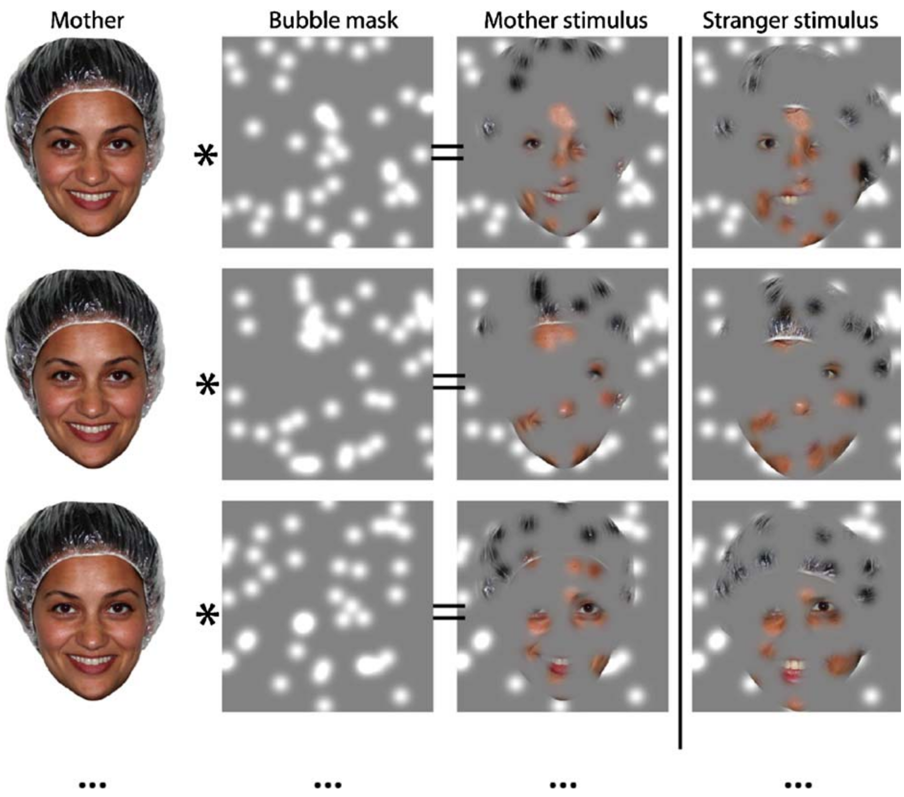

Fig. 1. Examples of the stimulus pairs used in the experiment. In the pair, one of the faces was the mother of the infant; the other face was unfamiliar. The same 'bubble mask' sampled information from the two faces to reveal information from the same face regions. The 'bubble mask' was composed of 40 Gaussian windows—bubbles—whose locations would randomly change across trials. In the experiment, each infant saw a total of 20 such stimulus pairs, changing the left-right location of their mother, and the unfamiliar face.

Fig. 1). Face pairs were viewed from a distance of 0.7 m and subtended a visual angle of approximately $16^\circ \times 16^\circ$, with an angular separation of approximately 20°.

Stimuli were presented on a single widescreen television monitor. An infra-red camera positioned centrally above the monitor was used to view the infant via a television monitor in an adjacent screened-off area and the session was taped on a VCR for later offline coding. Software to control stimulus presentation ran on a G2 Apple Macintosh computer.

The infant was seated in a car-seat with foam head support unless this could not be tolerated, in which case the infant was seated on the caregiver's lap, facing the display monitor. The experiment took place in a dark gray room, with the light dimmed, to minimize distractions. Caregivers were instructed not to talk or gesture to their infant when in the experimental room. When the experimenter could see that the infant was settled and looking centrally, and the video-camera had been focused in on the child's eyes, the experiment began. Each trial was preceded by a central attractor stimulus (an expanding and contracting target symbol, accompanied by electronic sounds) played until the infant was fixating centrally. Paired face stimuli were then presented (one to the left and one to the right of the screen) for a fixed trial length of 5 s. The location of the mother's face in the display alternated from left to right. Sessions were monitored and video-recorded by the experimenter. Testing continued until a maximum of 20 trials had been reached, or the infant fussed out. Left and right infant looking times were subsequently blind coded frame-by-frame from videotape by two trained observers.

2. Results

The babies performed a total 221 trials (on average 15.8 trials per baby, S.D. = 5.24, range 5–20) that were pooled together for analyses. The average looking times across all trials were mother: 1.34s (S.D. = 0.96s); stranger: 1.45s (S.D. = 0.96s). These did not differ significantly ($p > 0.05$). To compute the information subtending preference for a mother and preference for a stranger, we linearly regressed the centers of the bubbles (explanatory variable) presented in the experiment with the preferential viewing times (predictive variable) of the corresponding mother (or stranger) using the Stat4Ci Matlab Toolbox (Chauvin, Worlsey, Schyns, Arguin, & Gosselin, 2005). The resulting regression coefficients formed two surfaces (one for the mother and one for the stranger faces). Henceforth, we will call these classification images. We smoothed the classification images (by convolving them with a Gaussian window with a sigma of 5 pixels) and Z-scored them to enable application of the Cluster statistical test described in Chauvin et al. (2005). This test was originally proposed in Friston, Worsley, Frackowiak, Mazziotta, and Evans (1994) to improve the detection of wide signals in smooth volumes of data (in their case, hot spots in MRI data, in our case the eyes or the mouth of a face). This test provides a threshold for the probability of making an error in ascribing significance to a cluster of size K (or more) pixels. We restricted the test to the face area to increase sensitivity.

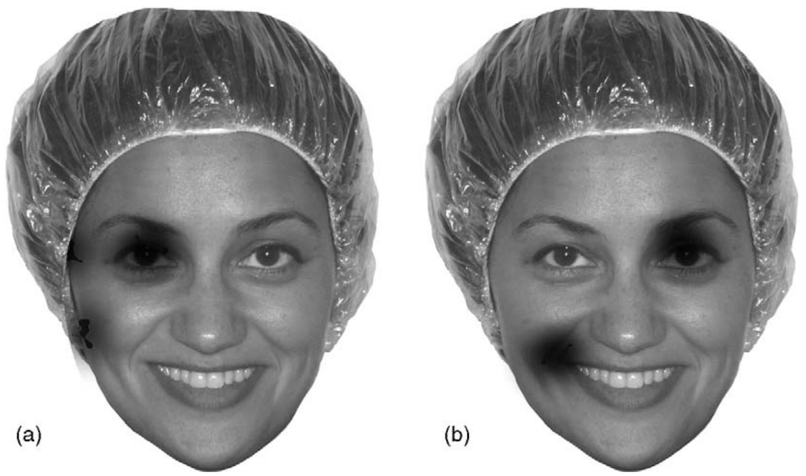

Fig. 2. This figure reveals the diagnostic information extracted from the experiment. (a) The information that 7-month-old infants use when looking preferentially at a stranger—mostly the stranger's right eye, but also contours of the face and hairline. (b) The information used to isolate the mother from a stranger's face—mostly the mother's left eye and the mouth.

Fig. 2a and b display the thresholded classification images. Only the clusters larger than the minimum size (i.e. 430.3 pixels, $p < .01$) are shown. The dark pixels indicate the regions that attained significance. A face is overlaid to facilitate interpretation. Fig. 2a reveals that the information associated with preferential looking to the mother's face is the left eye (or the right eye relative to the image) and the right side of the mouth. Fig. 2b reveals that the right eye and the left side of strangers' faces attract the attention of infants. This is despite the counterbalancing of these stimuli and presentation on both the infants' left and right.

3. Discussion

The primary aim of this study was to demonstrate the extension of the Bubbles technique to infant populations. In addition we wished to refine our understanding of the features 7-month-old infants use to view faces. Using a modified version of Bubbles (Gosselin & Schyns, 2001) in a preferential looking paradigm, we were able to demonstrate that the stranger's right eye region and right side of the face is associated with longer looking in 7-month-olds, and we infer that this region determines preferential looking to a strangers face. Furthermore this technique revealed that, in contrast, part of the mother's left eye and some mouth regions are associated with longer looking for this age group. Interestingly, about 80% of mothers hold their infants' head toward their hearts thus revealing them their left eyes (Salk, 1960). Because the mother and stranger classification images obtained are different we thus have evidence that the infants processed different information about their mother's face than that of a stranger.

Our results are broadly consistent with those of Cashon and Cohen (2001) in that both internal features (eye and mouth) and external features (part of the edge of the face) were used by the infants for face processing, and extend their findings to provide greater specificity about exactly which internal and external features are important (although we note that covering the hairline may mean we obscured some information that infants naturally attend to). The results are somewhat comparable with those obtained using the Bubbles technique with adults: Vinette, Gosselin, and Schyns (2004) found that for adults, a stranger's right eye became diagnostic between 47 and 94 ms after the onset of the stimulus and, after 94 ms, both eyes were used effectively.

This initial study demonstrates that the Bubbles technique is feasible for use with infant populations. Furthermore, it is to be preferred over existing approaches for investigating the informational basis of infant face recognition. These have traditionally divided the information available in faces into 'internal features' (the eyes, nose and mouth, and the way they are arranged) and 'external features' (the hairline and face contour) which are then manipulated independently (e.g., Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). However, while the distinction between internal and external features has proved a useful 'first cut' for investigating the information processed by infants from faces, it suffers from limitations. It is clearly over simplistic to divide the information in faces into only two types, and this places a low limit on the specificity of the results it is possible to obtain. In addition, we do not know whether this a priori division of the information maps exactly onto any distinction made in information processing in the brain (see also Rakover, 2002). The Bubbles methodology provides a way to investigate the informational basis of face recognition in infancy imposing as few a priori assumptions as possible (Gosselin & Schyns, 2001).

While the Bubbles method has advantages over some traditional infancy testing methods, some potential limitations need to be acknowledged. First, summing over infants means that some infants may contribute more trials than others to the analysis. Second, the nature of the masked stimuli may bias infants to apply a more featural, and less configural processing of the stimuli. Third, our experiment involved static face stimuli, and attempts to extend the bubbles technique to moving stimuli have only just begun. Nevertheless, we hope that, now the feasibility of using the Bubbles methodology with infants has been established, this will pave the way for further applications of the technique to visual cognition in developmental populations.

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